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SCHOOL SCIENCE AND MATHEMATICS

MARCH 1956

School Science and Mathematics

A Journal for All Science and Mathematics Teachers

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Life is not measured by days and years or by our creed, but by that which we think and do. Thoughts go booming through the world louder than thunder and more terrible than lightning, tearing their way into the deep recesses of human life where genius has slumbered and, touching the silent string of the soul, cause it to tremble with celestial fire.

CONTENTS FOR MARCH, 1956

School Science and Mathematics

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SCHOOL SCIENCE AND MATHEMATICS

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MODERN PLANT BREEDING PROCEDURES*

Harm Drewes
Eastern Research and Plant Breeding Station
Ferry-Morse Seed Co., Rochester, Michigan

Plant breeding, as the art of observation and selection, antedates recorded history. As long as man has cultivated the earth he has retained the good healthy plants and discarded the bad ones. Simple selection without use of controlled pollination procedures is undoubtedly the mode of origin of the many varieties we use in agriculture and horticulture, dating back to the remotest ages. This work has made extremely slow progress.

Man had to wait and see what nature could create, for hardly anything was known yet about the processes affecting plant life. Not until biology was fully developed, did this, in principle, change.

Plant breeding as a science is relatively a newcomer with the exception of an obscure paper published by Gregor Mendel during the time of our Civil War, having a few fumbling beginnings in the later part of the nineteenth century.

Modern plant breeding had its real beginning with the rediscovery of Mendel's Laws of Heredity at the turn of the century. The finding of Mendel's papers and the subsequent founding of the science of genetics laid the foundation for the science of plant breeding.

Single plant selection and selfing became, and still are, the basic work in plant breeding.

Consequent investigations of plant material in genetic research uncovered many useful tools for the plant breeder, with new and undreamed of prospects.

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* Read at the Biology Section of the Central Association of Science and Mathematics Teachers at Detroit, November 25, 1955.

The modern science of plant breeding is, in the first place, based on genetics and cytology but many botanical fields, such as pathology, physiology, taxonomy and biometrics contribute directly and importantly to the newer plant breeding techniques; also do certain branches of mathematics, physics and chemistry. All these, with the applied sciences in agriculture, such as horticulture, agronony and economic entomology furnish very useful tools for the modern plant breeder, opening newer and unlimited fields, a new era full of hopeful and never heard of possibilities.

In addition he must keep abreast of technological developments concerning culture, harvesting, shipping, processing and marketing of products of his development. This is particularly true in the case of plant breeders working with vegetable crops.

One of the outstanding discoveries was Dr. George Harrison Shull's discovery and development of *Heterosis* or hybrid vigor in corn, more than a quarter of a century before the acceptance of hybrid corn as a crop. Today more than 99% of important acreages of corn in the United States, both field and sweet corn, is produced from hybrid seed.

Inbreeding as well as crossbreeding play an important part in the production of hybrids.

Following hybrid corn, considerable emphasis has been placed on exploration of heterosis or hybrid vigor in many vegetable crops, such as onions, tomatoes, egg plant, squash, cabbage, cucumber, musk and water melon, carrot etc. Many hybrids of flowers are offered by the seed trade today, notably petunias and snapdragons. Not all show hybrid vigor. In the case of hybrid tomatoes for example the existence of hybrid vigor has been very difficult to prove. This, together with the high cost of seed production (hybrid tomato seed is produced by hand emasculation and pollination techniques) does not lend itself to large quantity production, but several tomato hybrids are offered in seed catalogs.

In recent years the discovery of a male sterile inherited character in the onion, followed by genetic study which established the nature of inheritance of the character has offered a new concept for the development of cheaper means of producing hybrid seed of many cross pollinated crops, such as onions, petunias and even corn. Eventually we may see the use of cytoplasmic male sterility extended to use in production of hybrids in a number of vegetable, flower and field crops.

Genetics, of course, is one of the major tools in plant breeding. Cytology or the very closely allied field, cytogenetics, have offered startling possibilities in plant breeding. Polyploidy in plants is found in nature, but can also be induced by the use of colchicine,

a dangerous poison. Tetraploids (which have double the norma number of chromosomes) of flowers and vegetables are already available.

In 1956 the Ferry-Morse Seed Co. will introduce a product from colchicine treatment in a zinnia, named New Century, of flower size and texture heretofore unknown in zinnia. This will bring new and exotic colors to the flower garden.

In the vegetable field there is the Beltsville Bunching Onion, created with the use of colchicine, as well as the seedless water melon. This triploid water melon seed is, at the present, mostly produced in Japan because of lower labor costs for this necessary hand pollinating operation.

Next to genetics, plant pathology is probably a close second in importance to the plant breeder. By the time that genetics became established as a science, some far sighted researcher awakened to the possibility of incorporating natural immunity to disease in cultivated plants. Since that time many new and important varieties have been added to the list of plants resistant to important plant diseases.

An example of how the fundamental aspects of a disease are used by plant breeders is our program of testing cabbage for yellows resistance. In this case we use pure cultures of the causal organism, *Fusarium oxysporium* form *conglutinans* in macerate suspensions in which roots of the lines to be tested are dipped and transplanted in sterile soil. They are grown over heating cables under thermal control to maintain the soil temperature at 18 to 21 degrees centigrade, the optimum temperature for maximum expression of the disease. After six to eight weeks the inoculated seedlings are evaluated for the disease on the basis of vascular discoloration in the roots.

In addition to diseases caused by soil born fungi such as cabbage yellows, we work with diseases which attack the aerial portion of plants. Some are caused by various fungi, some caused by bacteria and a number caused by viruses.

Search for sources of disease resistance may take many courses. Sometimes resistance may be obtained in cultivated varieties very similar to the types in which resistance is desired. Sometimes it is necessary to go to more distantly related kinds in the same species as for example in the search for club root resistance in cabbage. In this case practical resistance was found in the Siberian variety of kale far removed in plant type but of the same species as cabbage. A long and complicated breeding program is necessary to incorporate such resistance into types with desired characteristics.

Sometimes it is necessary to use different species for resistance, as for instance in tomato, where the common tomato (Lycopersicum esculentum) has been crossed with various wild tomato species, such

as *L. pimpinollifolium*, *L. hirsutum* and *L. peruvianum* to develop tomatoes resistant to *Fusarium wilt* and other tomato diseases.

Sometimes extreme ingenuity comes into play for disease resistance. For example, musk melons (cantaloupes) grown in California are very susceptible to powdery mildew. Finely powdered sulphur controls powdery mildew effectively but the plants are extremely sensitive to sulphur and were as severely injured by the sulphur as by the disease. Ferry-Morse plant breeders in California have developed a sulphur resistant variety which very nicely answered the mildew problem.

Knowledge of certain aspects of plant physiology are of importance to the plant breeder. In many plants, flowering response is controlled by photoperiod and temperature either acting together or independently. It enables the plant breeder to control flowering by manipulating the light and temperature when it is necessary to make crosses between plants normally having slightly different flowering times.

In all, plant breeding is becoming a very complex field, and the breeding of vegetable crops is among the most complex because of the wide range of species involved. It is necessary to test each potential variety in the potential growing areas. Growers' acceptance from such tests must then be followed by acceptance in the market, which is ruled more by the broker than the consumer.

Atomic energy may open a new field for the plant breeder. Results with radiation in crop improvement have been successful in some parts of the world but so far a very, very small percentage of radiation induced mutations are useful to man. Yet, this small fraction may be decidedly useful, and may play an important part in plant breeding in the future.

With all the background in science required of the modern plant breeder, the attributes of the more ancient art of plant breeding are still much in evidence. He must have an eye for making the right selections in his breeding program. Without this perception the vegetable breeder is soon out of business.

Desire not to live long, but to live well;
How long we live, not years but actions tell.

—Shakespeare

This world is my country, and to do good is my religion.

—Payne

Every noble life leaves the fiber of it interwoven into the fabric of the world.

—Ruskin

THE PLACE OF THE COLLEGE IN TRAINING TEACHERS TO EDUCATE STUDENTS AND THE GENERAL PUBLIC IN CONSERVATION*

RICHARD L. WEAVER
School of Natural Resources, University of Michigan, Ann Arbor, Mich.

With the increasing emphasis on conservation and resource-use education in public schools, there naturally arises a need for colleges to initiate or to increase their teacher training efforts in this field of instruction.

The criteria for planning such a program should be clearly defined and cooperatively developed if possible, inasmuch as many interests are involved.

Some of these criteria are specific to conservation and resource-use education, but many of them apply equally well to many fields of instruction. Some that find general acceptance among conservationists and educators are:

1. *Conservation demands an understanding of specific resources and problems involved in their use, but also of the interrelatedness of the resources one to another.*

This requires information on the a) *nature* of soils, forests, waters minerals, and wildlife, b) on the *extent* and *future prospects* for the resource, c) on the *problems* of extraction and use, d) on the *management techniques* available to increase or extend the resource, and e) on the administrative agencies and procedures established for the application of the technical "know-how" to the resolution of the problems.

The interrelatedness of resources is expressed as *ecology*.

Colleges usually have a general or an introductory course in Conservation or Resource-use which covers the specific resources. Some attention to the recreational resources and the human resources is given in most texts used in these courses.

Some colleges and universities such as the University of Michigan, Michigan State University, Purdue University and Wisconsin State College at Stevens Point have individual courses covering most of the basic resources. Some colleges also have special courses in ecology which help students see the broad interrelationships.

The Science departments or Conservation departments are the logical ones to handle the technical aspects of resource management found in these introductory or specific courses.

* Read at the Conservation Section of the Central Association of Science and Mathematics Teachers at Detroit, November 25, 1955.

However many geography departments have given such introductory courses and occasionally a course in mineral conservation.

2. *Conservation and Resource-use today demands an understanding of resource-economics, and resource-politics at the state, national and international levels.*

Some of these understandings can be incorporated into introductory courses, but usually they also need to be dealt with at greater lengths in specialized courses.

Here social science departments and particularly people especially trained in conservation can best cover these aspects of conservation.

At the University of Michigan we have two introductory courses, one emphasizing conservation in the United States, the other conservation in Michigan. Then in addition we have a course on International Resource problems, and another one on Resource Economics.

Some teachers' colleges have an introductory course for social studies majors and another one for science majors.

3. *Conservation and Resource-use education demands instruction and experiences in some specialized educational techniques such as leading field trips, using resource people and community resources, problem-solving, using and developing audio-visual aids, using school forests, gardens, and camps, and developing units of study emphasizing local resource-use problems.*

These are the techniques which will enrich teaching generally but are especially useful in teaching conservation and resource-use.

Such techniques cannot be learned from a text anymore than the nature or characteristics of specific resources.

Students planning to teach need real-life experience in the use of these techniques with children and adults.

Frequently workshops are designed as special methods courses where such experiences can be provided. Workshops also envision the development of units or plans of action which relate the content in conservation to specific school situations.

In one of our content courses, the one dealing with Michigan Resources I have the students do the research and planning necessary for them to present all of the content of the course, using as many of the above techniques as possible. Regular evaluations are necessary and checking of the outlines and plans as they are developed, if this plan is used.

4. *Conservation and Resource-use education demands a considerable emphasis on local resources and resource problems.*

Thus textbooks prepared for national use in public schools are not

as helpful as in some fields. If a text *is* used, it needs to be supplemented greatly.

Teachers being prepared for teaching conservation need experience in the development of units and projects in which the local resources are used and studied.

We provide this at the University of Michigan through several means a) experience in teaching a part of the course on Michigan resources b) development of units and some leadership experiences in the conservation workshop, and c) work experience by assisting in school camp, talking to assemblies, leading field trips, and assisting teachers locally with conservation projects. We have a conservation club through which these requests are channeled.

5. *Conservation and Resource-use education should include information concerning human resources and relationships.*

Such things as the origin and characteristics of the population, their cultural backgrounds and mores, their use of technical information, their employment, education, health, recreational opportunities and their concern for wise resource-use all should be considered a part of our conservation and resource-use picture.

The way people work together and the manner in which they take on new ideas or can be influenced to give leadership to a particular effort are new areas for many colleges and teachers. The behavior of groups, why they succeed or fail, and how they can improve is probably one of our best avenues for greater progress in conservation and wise resource-use.

This new emphasis, called group dynamics can express itself in classrooms by better methods of organizing our work, by small groups cooperatively planning and executing certain parts of the study, by decentralizing some of the work, and by evaluating all of the procedures and results regularly.

Workshops lend themselves especially well to the demonstration and use of these techniques, although parts of them can also be incorporated into other types of courses. I use some of these in the course on Michigan resources, where the students present the content information.

6. *Conservation and Resource-use education requires mastery of the communication skills.*

Some, in fact most of our school subjects do not anticipate any specific immediate action resulting from the instruction.

Conservation and wise resource-use recognizes the need for improvement and change in the application of "technical know-how" and "ethical-practices." It is built upon proper attitudes and be-

havior patterns. Thus there's more of a "missionary incentive" involved.

This requires greater emphasis on our ability to use speech, debate, the printed word, radio, television and other audio-visual aids in getting ourselves understood and bringing about behavioral changes.

Thus colleges need to increase their emphasis on this and provide greater opportunities to have rich experiences in these techniques.

Teachers cannot be expected to improve their abilities in these things merely by observing a master teacher using them effectively. In fact many college teachers do not even demonstrate them very effectively.

In our University of Michigan program of training teachers and other conservation leaders, we are endeavoring to get a three-way balance in our instruction at the graduate as well as the undergraduate level. We prefer a third emphasis on the natural sciences, a third on the social sciences and another third on the communication skills.

We have an undergraduate major in conservation in which a teaching certificate can be obtained, a master's sequence in conservation and outdoor education in the School of Education, as well as a master's and doctor's program in conservation in the Graduate School.

Many of our faculty have joint appointments in other departments, such as botany, zoology, economics and education.

We try to keep our scientists in close touch with teachers' problems by having many of them assist with off campus courses for teachers. One operated for ten weeks requires ten staff members, each leaving the campus for a week at a time and appearing at five course centers during the week.

Summary

1. Colleges need to re-examine their courses and programs in conservation and resource-use in the light of the new demands being made upon them.

2. All colleges and universities need at least one introductory course in conservation which covers the basic resources and the principles of resource-use. Additional specialized courses are needed to adequately prepare teachers wanting to specialize in conservation. Areas frequently omitted are resource economics, international aspects of resource development, and ecology.

3. A methods course or conservation and resource-use workshop is essential if experiences are to be provided in many of the techniques which have special application to conservation and resource-use education such as field trips, audio-visual, problem-solving, group

dynamics, school camps, forests, gardens and other outdoor laboratories.

4. Teachers need practical work experiences with emphasis on "How to do it," and opportunities for them to develop their own skills in the numerous techniques necessary for enriched learning in conservation and resource-use.

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2. American Council on Education, Committee on Southern Regional Studies and Education—*Guide for Resource-use Education Workshops*, 46 pages, 50¢; 1785 Massachusetts Avenue, N. W., Washington 6, D. C.
3. National Association of Biology Teachers—*Handbook for Teaching Conservation and Resource-use*, 500 pp. 1955. P.O. Box 2073, Ann Arbor, Michigan.

TEACHING AS A CAREER

Teaching as a Career. By Earl W. Anderson. Office of Education Bulletin 1955, No. 2. 20 pages. For sale by the Superindendent of Documents, U. S. Government Printing Office, Washingron 25, D. C. 15 cents.

Any young man or woman who is considering teaching as a career should seek answers to the following questions: How important is teaching? What does a teacher do? What are the requirements for teaching? How may I meet them? How can I give satisfactory employment in teaching? What salary will I receive? What are the retirement provisions? Will I enjoy teaching? Answers to these questions are given in *Teaching as a Career*.

In this bulletin of the Office of Education, it is pointed out that capable young people prepared for teaching will find great demand for their serivces in the immediate years ahead. It is expected that the present critical need for qualified elementary school teachers will continue for many years. In addition, the present shortages of high school and college teachers in mathematics, science, and technical fields will, according to predictions, spread to virtually all subjects as the large numbers of students now in the elementary schools move on into the high schools and later into the colleges.

Teaching as a Career is published as a much-needed service to men and women considering preparation for teaching.

ECOLOGY CENTER ESTABLISHED AT WESTERN MICHIGAN

As the result of a very generous gift and the hard work of some Western Michigan College faculty members, the local campus may well become one of the World's leading centers for information in the field of ecology.

Just received on the campus is the first half of the library of the late Dr. Charles C. Adams, former president of the Ecological Society of America and acknowledged to be one of the world's foremost ecologists before his death last April in Albany, N. Y., at the age of 82.

The entire collection has been valued by two independent dealers at between \$30,000 and \$40,000. Some idea of the extent of the books and pamphlets may be gathered from the fact that this initial shipment weighed 11,000 pounds.

THE ATOM GOES TO SCHOOL

Maitland P. Simmons*
Irvington High School, Irvington 11, New Jersey

With the every-increasing and constantly changing industrial growth in our country, there is a definite need for the strengthening of science research in the new and expanding technologies, such as electronics, atomic energy, and automation.

Since many of our secondary public schools are overcrowded, and teachers overworked in many areas, the intellectual youth is not being discovered and utilized to his full potential. Therefore, in the light of the present situation, it would appear that the first phase of the problem would be the identification of these science-minded students with high level abilities, particularly in the area of science and engineering. To recognize these traits, one should examine their intelligence-test scores, achievement records, especially in mathematics and English, reading scores, personality ratings, attendance records, and extra-curricular activities. Other contributing factors include willingness to attempt difficult tasks, to spend extra time, to withstand discomfort, and to face failure. The guidance counselor can furnish you with cumulative records and other pertinent data.

With this all-important information, the next task is to develop a specific program geared to their comprehension. One approach would be to encourage and inspire the latent-talented young scientist in the selection and the full completion of a worthwhile intensive research project. In many instances the prospective scientist will have an opportunity to demonstrate his creation at some science fair. Many science-related industries and learned societies frequently assist these young people in this human endeavor.

Below is a pictorial example with a brief description of how a gifted ninth-year student actually developed one of these scholarly projects, Nuclear Energy Going to Sea.

For factual material, a vast collection of newspaper clippings, magazine articles, photographs, and informative letters from the General Electric Company were used. The home, school, and town library proved to be a valuable source of help. Construction plans followed, and from these the display was ready to be set up.

STEP 1 shows a scale model of the atomic-powered USS *Seawolf* made of balsa wood consisting of approximately 500 pieces. This part of the activity required painstaking effort since every piece was handmade. To accentuate the portholes and the bridge of the ship, small lights were installed in the model. After painting the submarine

* On committee for the Greater Newark Science Fair and past-president of the New Jersey Science Teachers' Association.

a battleship grey, a periscope and twin-screw were then attached.

STEP 2 depicts a cutaway scale model. This was constructed to show the location of the nuclear power plant and its relative size as compared to the submarine. To make the power plant stand out, a headlight from a Model "T" Ford was used as a spotlight. This model was left unpainted to give the effect of the ship while in the process of construction.

Charles Lacefield, Irvington High School, points to his cutaway scale model of the atomic-driven USS *Seawolf*.

STEP 3 shows the operation of the entire atomic power plant. First, a nuclear reactor was built by substituting a heating unit from an electric coffee pot for the atomic "match" or trigger and a pint can as the reactor core. An insulating material was used to form the heavy lead radiation shield. Next, a heat-exchanger was made from a quart juice can. A turbine was then carved from a solid piece of balsa wood to which was attached a small battery-driven motor having an extended shaft. At the end of the shaft, a propeller was securely fastened. A copper tubing was then run from the reactor. through the heat-exchanger, into the turbine. The open end formed the outlet for the excess steam. For the fuel, instead of uranium 235, water was used in the reactor core.

After construction came the painting of the parts of the power plant. Various color combinations were used to produce standout appearances. The insulating shield was painted aluminum to give a lead appearance. The heat-exchanger was painted green, and the turbine, red with black and white trimming. Small identification cards were then glued to each part describing them. The final step included a typed report and the designing and painting of a large colorful explanatory poster, which was fastened to the back of the exhibit.

For this outstanding piece of work, an Honorable Mention Certificate was presented to the boy at the greater Newark Science Fair. Considerable enthusiasm was aroused among students, parents, teachers, and friends when this unusual, large-size, attractive exhibit was demonstrated at the Suburban Essex County Science Fair Conference, an American Chemical Society Contest, an Irvington High School Assembly, and a General Science Sectional Meeting of the New Jersey Science Teachers' Association.

From this worthwhile experience, the student gained recognition, prestige, and fellowship, so important in the creating of a well-rounded personality.

The outcome of this teacher-sponsored experience all adds up to a future job possibility leading to a career in science.

SCIENCE FELLOWSHIPS AT M.I.T.

A national competition for fellowships for high school teachers of chemistry, physics, and biology throughout the United States to attend a special program at the Massachusetts Institute of Technology during the summer of 1956 was announced by M.I.T. this week.

Dr. Ernest H. Huntress, director of the M.I.T. Summer Session, announced today that generous assistance from the Westinghouse Educational Foundation will make possible a total of eighty fellowships to help meet the costs of attending a special program.

First established in 1949, this program will be the eighth offered to science teachers by the Institute. During this period 371 teachers representing all but two of the 48 states have participated as winners of Westinghouse Fellowships.

This year's fellowship winners will attend a six-weeek program of study at M.I.T. from Monday, July 2 through Friday, August 10. Designed by a special faculty committee, this program will provide a review of fundamental subject matter in physics, chemistry and biology, and a survey of recent scientific developments not only in these fields but also in meteorology, geology, and aeronautical engineering.

Applications for Westinghouse Fellowships for the 1956 Science Teachers' Program will be considered only from experienced high school and preparatory school teachers of science who hold college Degrees or who have had substantially equivalent training and background, according to Professor Huntress.

Further information on the Science Teachers' Program and application blanks for the Westinghouse Fellowships may be obtained from the Summer Session Office, Room 7-103, Massachusetts Institute of Technology, Cambridge 39. All such applications must be filed by April 1, 1956.

THE INTERPRETATION OF DATA WITH APPLICATIONS IN ELEMENTARY ALGEBRA[1]

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The flood of advertising on the various communication media, the yearly increase in the number of accidental deaths and injuries and many other indications of laissez faire attitudes, seem to show that the citizen must become more sensitive to the need for becoming proficient in his ability to interpret data. A very precious possession of a democratic culture is the freedom and privilege to interpret data. The ability to interpret data strikes at the heart of democracy, for citizens alert to the techniques of interpreting and evaluating evidence are democracy's bulwark. With a citizenry apathetic to the wiles of those who would misinterpret data, democracy becomes ripe for plucking by any group with a consuming desire to replace democratic ideals with authorititarian or other anti-democratic ideals. The growth and development of a democracy may well be gauged in direct relation to the number and quality of persons sensitive to the validity of the many generalizations made in the daily press and other written materials.

The ability to interpret data can best be defined through a description of the various behaviors one displays while engaged in this process. How would a person behave who knows how to interpret data?

Probably the most important behavior is represented in the action of perceiving and expressing possible relationships between items in a set of data. The data may be presented in tabular form, in graphic form, in a verbal statement, or in any form which conveys the relevant information. A person in the act of interpreting data can see the existence or non-existence of a relation between elements or variables in a set of data and can make appropriate expressions of such relationships. The term "variable" is used with a much wider scope than its use in classical mathematics.

There are many supplementary skills required in order to perceive relationships in data efficiently. For example, in a functional relation involving two variables one should be able to compute the values of a variable from known values of a related variable. This includes an understanding of the changes in a variable when a related variable undergoes a change.

[1] For a more comprehensive discussion of this problem consult: William N. Jackson, "The Role of Algebra in the Development of Relational Thinking," unpublished Doctor's Dissertation, Columbus: Ohio State University, 1952.

One must be able also to relate like characteristics in different types of data. Recognizing the relationship between the slope of a graph and the constant differences between the values of the dependent variable in a table is an illustration of this ability.

The ability to do symbolic thinking such as attaching appropriate meanings to various symbols is a very important supplementary skill. Without this ability the interpreter of data would be in much the same predicament as the surgeon who plans to operate but has no instruments.

Recognizing the limitations of data is a second characteristic of the interpreter of data. With this ability he knows how far to go in drawing inferences from data. He uses procedures appropriate for identifying tendencies or trends in a given set of data. He makes proper qualifications of his statements when interpolating or finding and using intermediate values of the variables. The same may be said of his statements when extrapolating or predicting values of variables greater than the largest in a table of data or which lie beyond a given graph. Hence, he will use such terms as: "it is probable that," "some," "many," "almost," "it appears that," in making interpolations and extrapolations. He is also mindful of the type of sampling in data, and considers its representativeness as well as the amount of data preparatory to making interpretations. He recognizes the need for enlarging the data before stating or accepting some interpretations. Obviously, he must use the data appropriate for the particular situation and consider the domain of the independent variable and the range of the dependent variable.

In handling data, the interpreter realizes that his inferences cannot apply to a single individual or item, that his inferences must be tempered with qualifying terms which inform others of the degree of uncertainty of his predictions or explanations. The interpreter of data must understand the difference between a scientific law, which applies in every instance, and statistical generalizations which are rendered uncertain through probability.

A third behavior often displayed as one interprets data is a sort of open mindedness on the part of the interpreter. He understands that, in many situations, absolute interpretations cannot be made because of the changing factors or variables which are contained in the interpretations. He understands that the degree of truth in a declaration is dependent upon the extent to which the related variables approach non-variability. Concerning this, Thouless says:

> All over human life we find properties which show continuous variation, and we find this property obscured by the use of words implying sharp distinctions. "Sane and insane"; "good" and "bad"; "intelligent" and "unintelligent"; "proletarian" and "capitalist," are pairs of opposites which show this property of

continuous variations. . . . Any argument, therefore, which begins in some such way as follows: "A man must be either sane or insane, and an insane person is absolutely incapable of reasonable thought . . . ," is a dangerous piece of crooked thinking, since it ignores this fact of continuity.[2]

The interpreter of data realizes that many relations are propositional; they have neither validity nor invalidity when the variables which compose them have no specific value. For example, the statement that "Catholics do not cooperate with Protestants" is a proposition—it is neither true nor false. When "Catholic" and "Protestant" are given specific values as "John Baker does not cooperate with Albert Saunders," the statement may be rated as true or false, depending on the actions of the two men. Many times we are led to rate such generalizations as true after one example is cited in which specific values are given to the variables. A person sensitive to the nature of propositional functions will, in his reading, recognize statements which actually are neither true nor false because they are generalizations with no specificity given to the variables. He will try to determine the writer's belief with respect to the statement and analyze the data given in support of it.

The interpreter of data is not only open-minded; he is also critical minded. A fourth behavior which he displays is the appraisal of generalizations drawn by others in their interpretation of data.

A critical minded person would look for the number of cases cited in an argument and for the variety of the sampling. In evidence produced through testimonials he would consider the qualifications of the person testifying. He would question the testimonials of well-known athletes, movie stars, and other noted persons concerning products and ideas beyond their particular fields of attainment.

Finally, one skilled in the interpretation of data must be able to draw valid generalizations consistent with relationships which he recognized. For example, the table below charts the distance a moving car will go between the interval when the driver decides to apply the brakes and the actual application of the brakes. This interval is known as the "reaction time," and the table is based upon the average reaction time which is one half second.

Suppose after inspecting the table, a student notes the following relationships:

1. When the speed is increased from 20 mph to 40 mph, the reaction distance is doubled.
2. When the speed is increased from 30 mph to 60 mph, the reaction distance is doubled.
3. When the speed is increased from 40 mph to 80 mph, the reaction distance is doubled.

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[2] R. H. Thouless, *How to Think Straight*, New York, Simon & Schuster, 1931, pp. 122–123.

In making these observations he has recognized a specific relationship between the variables, speed and reaction distance. However, if his analysis stops at this point, he has failed to generalize the relation which he has recognized. The climax in such an exercise is reached when the student is stimulated to state that, "the data indicate that whenever the speed is doubled, the reaction distance is doubled." The making of such generalizations, with necessary caution, is a characteristic of the student learning to exercise his intellectual powers to the maximum. Failure to encourage the practice of this important behavior would be a serious indictment against any mathematics teacher who desires to train young people to become competent members of a democratic culture.

SPEED AND REACTION DISTANCE

Speed in Miles per Hour	Reaction Distance in Feet
20	$14\frac{2}{3}$
30	22
40	$29\frac{1}{3}$
50	$36\frac{2}{3}$
60	44
70	$51\frac{1}{3}$
80	$58\frac{2}{3}$

The behaviors described with respect to the ability to interpret data, although applicable in the solution of mathematics problems, apply with as much force to any situation which could be resolved effectively through use of the ability. Whether the data be concerned with a basketball tournament or a sermon, an advertisement or a graph of a linear function, the behaviors apply in all situations. For this reason a teacher much provide a variety of situations in the classroom aimed at generalizing the behaviors involved in the interpretation of data.

Regardless of the desirability of the behaviors needed for interpreting data, they cannot be "served" to the student to be siphoned off at will. The teacher must plan ways to help students make genuine use of the behaviors in all situations—whether academic, personal, or social—where they can function for the benefit of the user. There must be persistent effort made to help young people understand the value of their use in life situations. If interpretation of data becomes an objective of classroom instruction, then to no less degree should the generalizing of behaviors associated with it also become an objective of instruction.

He hurts the good who spares the bad.

—SYRUS

THE CASE FOR COLLEGE GEOMETRY

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No neophyte in a mathematics classroom is expected to teach algebra to high school students with only the algebra he has learned in high school himself as a requisite. On the contrary, his college training will surely have included college algebra, theory of equations and perhaps courses in the theory of numbers, higher algebra, or abstract algebra, to say nothing of required courses in analysis. Then he is sure to have had a certain number of hours in education and in "methods"—how best to present the mathematics that he knows. All these things are true whether the young teacher is the graduate of a teachers' college, or whether he is the product of a liberal arts college.

But if one examines the plight of high school geometry, the story is entirely different. It is assumed that the teacher of this subject should be able to impart the knowledge of this discipline on the strength of what he learned in high school. (This is a gratituitous assumption since four years of college without geometry tend to make the student forget what he learned in high school.) True, many colleges offer courses in college geometry or modern geometry. In few is it a requirement. However, requirement it should be, at least for all those who intend to teach, or the quality of high school instruction will tend to decline, there will be fewer high school students electing to take mathematics in college, and the vicious circle will continue.

By college geometry is meant that body of theorems, Euclidean in nature, that are extensions of those taught in high school, and especially those that were developed in that fruitful period at the end of the nineteenth century. This would include work on the nine-point circle, the Simson line, poles and polars with respect to a circle, Brocard geometry, and inversion. In most colleges it is an elective, three-hour course, if it is given at all.

The Committee on the Undergraduate Mathematical Program with W. L. Duren, Jr. as chairman, reporting in the *American Mathematical Monthly* for August-September, 1955, suggests a partial list of special problems on which work is needed in order to attain the objectives of modern mathematics teaching in colleges. One of these topics is "the resetting of geometry in the curriculum." Every college requires analytic geometry in some form or other. Why is there not further work in its neglected companion piece, synthetic plane geometry?

A course in modern geometry would give the student an excellent review of his high school course besides providing him with an op-

portunity to analyze new problems and devise methods of proof for them as he will have to do when he stands in front of a class himself. It will show him that the theorems taught in high school are frequently special cases of much more general theorems (although the particular often antedated historically the general), or that the elementary theorems may be proved much more elegantly and simply by recourse to modern theorems based on the usual Euclidean postulates also. Think how easily, for example, one can prove the concurrency of the medians of a triangle, of the angle bisectors, and of the altitudes by means of Ceva's theorem. It is good for the student to learn that the Pythagorean theorem is a special case of Ptolemy's theorem when the cyclic quadrilateral becomes a rectangle. Finally, no student of mathematics should be graduated from college without being initiated into the beautiful and simple properties of the nine-point circle. These properties may later be profitably introduced to his high school class or club.

More than twenty-five years ago Nathan Altshiller-Court, writing in the May, 1924 issue of the *American Mathematical Monthly*, listed cogent reasons for teaching the geometry of the triangle in college. He even included the incentive to research that modern geometry provides, for one can looking for relationships himself with a not-too-extensive knowledge of the subject, whereas research in a field such as analysis presupposes a tremendous background before anything original can be attained. Since he wrote his article, Altshiller-Court has brought out two editions of a textbook on college geometry; others, such as Davis and Daus have written books; and the number of students who have been introduced to the subject in the past quarter of a century has increased. But the number has not increased rapidly enough, and college geometry is currently an unfashionable subject. The reasons advanced by Altshiller-Court for the study of the subject years ago are just as valid today. Courses in projective geometry and in topology certainly widen the horizons of the prospective teacher and enrich his cultural background. Surely he should know these things. So should he know about set theory and Boolean algebra, and digital computers, but these are not of specific value in the teaching of high school geometry, and it is high school geometry that must be well taught and enthusiastically taught if there are to be any mathematicians in the future.

Fog Horn for use on small boats blows its own warning using refrigerant gas. Independent of electrical or mechanical power, the liquefied gas under pressure is routed through a whistle when the alarm is needed. The trigger-operated foghorn weighs just under four pounds and emits a continuous 12-minute blast audible for at least one mile.

RESOURCE STEWARDSHIP IN A PROGRAM OF EDUCATION*

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It is an inspiration for me to be here and to listen to successful scholars and eminent scientists consider values in two challenging fields—Science and Mathematics. I am pleased you have chosen to include in this 1955 progrm, wise resource use in a program of education. It is with trepidation that I proceed, however, since I am fully aware that "Fools rush in where wise men fear to tread."

To give me a frame of reference for my number, I asked Dr. P. L. Whitaker of Indiana University to prepare five or six questions which might serve as a basis for my discussion. As a result, I have been reassured concerning two previously held convictions—

1. Professors can and do ask the hardest questions.
2. The quality of one's questions are an accurate determinant of the depth of one's intelligence and, so on the basis of his questions, if I had the power, I should confer upon Dr. Whitaker the prefix "Super-Duper" to precede his doctorate title.

The first question is—

> How can the State Department of Public Instruction best utilize the various professional conservation institutions and organizations in the state to promote conservation education through the school system?

I hesitate to try to answer this question with the implied positions of the institutions in the program. By implication, other institutions are secondary to the Department of Public Instruction. In my opinion there are four basic coordinate centers where action should be started—four centers of responsibility:

1. Superintendents, Principals, local Boards of Education, Teachers and lay people—those included in the immediate learning centers.
2. The Department of Public Instruction.
3. The Conservation Department and other Conservation Agencies.
4. Administrators, Directors of Teacher Training, teachers of our teacher education centers—colleges, etc. Seats of pre-service and in-service teacher education.

These significant centers of action should move together if possible. They must become "Partners in the progress of resource use in public and private education." They should be coordinate in the assumption of responsibility and in the work involved.

I visualize these four factors as a well machined, smoothly running, efficiently operating four cylinder engine geared to results in resource education. To render the power and achieve production commensu-

* Read at the Conservation Section of the Central Association of Science and Mathematics Teachers, Detroit, November 25, 1955.

rate with the job, each cylinder must make its fair share of the total contribution, and all four must be properly synchronized. A dead cyclinder not only results in a loss of drive, but more than that, serves as a drag on the whole machine.

Our first job, then, should be to start this partnership for progress with as many as will participate, and work for a united front which will involve all four factors.

Having identified the leadership front, let me move to the job at hand. What does it include? What steps are involved?

I. There is need for identification of resource problems, for a recognition of what the school can do toward their solution, and for an expression of the school's responsibility in reference to the job to be done.

These responsibilities must be carried on in the four previously mentioned centers. Leadership work, of course, rests heavily upon the Conservation Department and other Conservation Agencies, since they possess the conservation "know-how" which is the heart of the program. Leadership work as well rests heavily upon the Department of Public Instruction and other school agencies, since upon them rests the "know-how" factor of the educational process.

While the educational program might be started as indicated, the lay people must be early participants not only because of their advantageous location, their financial investment, their possession of the children, also because they have a leadership reserve that should be tapped. The schools belong to all the people, and Boards of Education will be reluctant to move forward without grass roots understanding and support, if, indeed, they will move at all without a lay request.

To move reasonably well along the entire front, it should be clearly understood that you can't have good conservation education without good education—likewise education won't be reasonably functional and reasonably well balanced without resource education as a part of it.

II. Secondly, once the initial interest is catching fire, the development of purposes, policies, plans and suggestions as to practices should follow. This is necessary to broaden the base, develop clarifying understandings, and make possible a coordination of effort in both pre-service and in-service work. Unity of purpose and coordination of effort are prime factors in a program of progress.

The following are some of the problems which should receive attention in this unity and coordination phase of the program:

1. How shall conservation be defined?
2. Shall ecological relationships be recognized as the real heart of the program? If they are, can corresponding materials be found to implement the program?
3. What broad objectives should be formulated which will give direction, and also serve as progress posts against which to evaluate?

4. Shall resource education be made an all-pervasive factor with resource ideals and principles permeating the whole education program?
5. If the school offerings are subject channelled, which values may be included in the sciences, which in the social sciences, and which in other areas of the school program?
6. Since all teachers will not have equal opportunity to emphasize resource values, shall teacher education be concerned with the preparation of those who have major responsibility, or shall all teachers be given the work, and all be prepared to have a share in it?
7. How can teacher education centers meet their responsibility in reference to it? What arguments can be used to encourage its placement in the crowded college offerings?
8. Shall central workshops be set up for in-service education, if not, how shall this important work be carried on?
9. Shall equal emphasis and the same kind of offerings be given to urban youth as are given to rural youth?
10. What part should the local community occupy in the program?
11. How can conservation agencies contribute to such work? Do they have a field guidance responsibility, or should they confine themselves to writing pamphlets and books?
12. What part should teacher certification have in the program?
13. How shall supervisors function? What is their part in the program? What help should they have?
14. Should there be a state resource education coordinator? If so, how should he function, and where should he be located?
15. If there is an overall program of education for the state which is guided by a state central curriculum organization, how should resource education be fitted into this program?
16. What kind of legislation, if any, is needed?
17. What kinds of materials should be provided for the assistance of administrators, principals and teachers?

These and many more problems must be considered if resource education is to move forward with unity of purpose and coordination of effort.

III. A third responsibility is the development of a curriculum framework or structure to expedite overall resource curriculum planning, and to assist teachers in a recognition of where each fits into the program.

A framework such as I have in mind, and such as we are working upon, can do four things—

1. Help superintendents, principals and teachers to obtain an overall suggested curriculum framework.
2. Give guidance which will assist those who are planning programs to avoid many of the omissions and overlappings frequently found in school offerings.
3. Give teacher education centers something to work on as a basis for activities with prospective teachers.
4. Serve as a basis or a frame of reference for the development of a scope and sequence for the school.

The latter is highly essential. And we who have the broadest and most experienced backgrounds have hedged on one of the most significant jobs, that of suggesting what should be done on various learning levels.

This framework is not intended to be a firm and fixed structure,

but rather a suggested one. It proposes a problem solving procedure, with one or two problems for each grade, each one an inclusive problem, and each containing a resource core—kindergarten through high school. Accordingly, a resource thread will run vertically through the curriculum. In addition, teachers will be encouraged to include resource values when and where opportunities arise.

The following is the framework upon which we are working at the present time.

Kindergarten—What do our plant and animal friends do to help us in our school and school surroundings? (These will offer opportunity to tie in the soil, water, sunshine etc.)

Grade 1—How do our plant and animal friends help us to have a happy, healthful, attractive and productive home?

Grade 2—How do our parents and neighbors depend upon nature's gifts for food, clothing, fuel and shelter? How can we help to use these natural gifts wisely?

Grade 3—How does our community help us, and how can we make it a better place in which to live? (Homes, streets, parks, playgrounds, public buildings.)

Grade 4—How are Wisconsin's resources contributing to the life and living of our people?

How were resources used in early days, and what can we learn from such earlier use?

How do resources contribute to (a) Rural progress (b) Urban progress (c) Tourist satisfactions and success?

Grade 5—How are the resources of the U. S. and Canada contributing to the greatness of those two countries?

How did early resource use contribute to early exploration and settlement, and what can we learn from such use?

How can we use our resources to the best advantage for ourselves, for other people, and for future peace?

What course can we pursue that will be of mutual benefit to ourselves and to other countries?

Grade 6—What can we learn of our birds, fish, flowers, trees and weeds? How do they fit into nature's scheme of things? How do they help or hinder man in his life pursuits? What are man's responsibilities in reference to them?

Grade 7—What are some of the many problems that we meet in the use and management of our resources—soil, water, forests, wildlife etc. which are evidences of the dynamic processes of nature? What can we learn about nature's balancing processes? How and to what extent are balances being disturbed? How and to what extent is man involved in these disturbances?

Grade 8—How can we wisely manage our natural resources to the end that we may live advantageously and pass on an even greater heritage than we have received?

I should culminate management studies with a concentration upon good management of a rather large watershed, and the management of farms within it. In this study, pupils should learn the interrelationships that are involved in resource management.

Grade 9—What constitutes good conservation citizenship?

What institutions concerned with resource use do we have to help us with our problems of wise use and efficient management?

How is our State Conservation Department organized? What services does it perform?

How can we organize a local conservation unit?

What might well be included in its program of activities for a year?

Grade 10—What are some of the biological concepts which if applied to our resources will expedite a program of wiser use and more efficient management?

Grades 11 and 12—What are the social responsibilities which should be assumed in our democratic life which concern wise use and efficient management?

What impacts have resources had upon past wars and conflicts?

What responsibility do we have in the matter of distribution?

Should there be non-reciprocal distribution if such will help to keep the peace?

If possible, I should like to have the work of all levels pointed up in this grade and climaxed with a recognition of the social significance of our resources at home, with neighboring countries and with more distant lands.

IV. A fourth responsibility is the development and enrichment of a scope and sequence by and for the local school.

Time does not permit the discussion of this nor the last step Number V.

V. There should be continuous evaluation with constant corresponding application of effort toward further improvement as new vision comes to the leadership in both resource and education fields and new problems arise.

1. We are planning our school program so as to have a unit with a conservation core on each grade level, thus providing a vertical conservation thread extending through our elementary and secondary school offerings.
2. We are using the problem approach in our planning.
3. We are including conservation offerings without upsetting the on-going curriculum program.
4. We hope to have it carry factors of especial interest as well as elements of challenge on every grade level.
5. It will be an action program.
6. It deals on each level with the dynamics of nature, and human values and moral implications will be drawn in keeping with the possibilities which each lesson affords.
7. The guidance materials will encourage flexibility, making possible the substitution of a problem in place of the one suggested if that is the wish of the local school.
8. So far as possible, we shall avoid the traditional soil, water, wildlife and mineral break down, and will emphasize ecological aspects and relationships.
9. The "here and now" will be given first consideration, the historical implications secondary.
10. Teachers are encouraged to give consideration to concept development. We hope to have these evolve naturally.
11. We shall continue to develop rich resource libraries.
12. We shall continue to draw abundantly upon local successful farmers and resource specialists.
13. Desirable correlation and integration is encouraged.
14. Flowers, birds, weeds insects, etc. will be given in-season consideration on all levels, but they will be pointed up especially in the sixth grade.
15. Correlation and integration will be encouraged on all levels whenever and wherever opportunities appear. On the high school level where offerings are more largely subject centered, each teacher will be encouraged to develop resource understandings, attitudes and appreciations in keeping with the subject or area to which he is assigned.

Resource education can only reach its finest level when human implications, related social understandings and economic aspects are put in perspective with each practical lesson. Experiences, then,

will not only be concerned with fertile soil, pure water, productive forests, abundant wildlife and the sane and sensible use of minerals, but these will be put into a setting of fine homes, efficient schools, beautiful churches, and successful communities. How unwise for people though possessed with rich abundance, to live in personal want, and in school, church and community poverty. How immoral, on the other hand, for those blessed with abundance to selfishly waste the rich resources which have made this country the envy of the world so that neither the individuals and institutions of today, nor those of the future can serve to their fullest.

Finally, with the ardor and resource evangelism that comes to youth, as day by day under sympathetic and stimulating teachers the rich lessons of life unfold, I should want him to see clearly that as he gives to nature, so is there returned to him not only rich material blessings, but a pricless personality enrichment which will serve as a source of service and satisfaction throughout his earthly life.

SCIENCE TEACHERS, ATTENTION

The University of Wisconsin has received a grant of $249,700 from the National Science Foundation to inaugurate an experimental program to train high school teachers to teach science and mathematics more effectively.

The program will begin next fall with 50 high school science and mathematics teachers, chiefly from Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin. Prof. Harvey Sorum of the University of Wisconsin's chemistry faculty will direct the program at Wisconsin.

The program is first being tried at the University of Wisconsin and Oklahoma Agricultural and Mechanical College. If successful, it will be expanded to a total of eight schools in the academic year 1957–58 with the idea that advance teacher-training in the field of science would become a continuing program in which science teachers in all parts of the United States could participate.

Each teacher will receive $3,000 with an additional allowance of $300 for each dependent, plus tuition fees and travel allowances, the Foundation announced.

The Foundation said the purpose of the grant is to launch an experimental program designed to assist colleges and universities in their effort to improve science training for high school teachers.

Each teacher selected to participate in the program will pursue studies designed to increase individual effectiveness as a teacher, and each will be able to take refresher courses in the fundamentals of biology, chemistry, mathematics, or physics, seminars in teaching methods, regular university science courses, and university courses devoted to the influence of science upon modern life.

To be eligible for selection to participate in the program a teacher must have a bachelor's degree, have taught for three or more years, be teaching science or mathematics, show scholastic and teaching ability, and be under 46 years of age, the Foundation said.

FINANCING FUMES

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Not all discards are dumped into the garbage can. They sometimes go up the chimney. When wastes escape as fumes, however, they are not always fully discarded. Their effects often return to plague their producers. The Murry plant of the American Smelting and Refining Company of Salt Lake City can testify to that. In 1920 that company faced a suit seeking restraint of their operations. The charge was: "(production of) noxious gases and air-borne noxious waste materials." From that action came a court order that "(all) furnaces and flues (hereafter) be maintained without leaks and (that) gases and air-borne wastes be bag-filtered or Cottrell precipitated for removal of sulfur trioxide, sulfuric acid and suspended solids."[1]

Installation for execution of that court order entailed heavy outlays for plant modification and expansion. Any one sensitive to a sense of equity would understandably ask, "Did that public interference with industry cripple it?" The answer is found in what the company did with its reclaimed "noxious wastes."

Iron's Blast Furnace Fumes

Perhaps the earliest industrial fume-producer was the iron ore smelter. Man first used iron around 1000 B.C. He, of course, did not then produce it by modern blast furnace methods. When the blast furnace principle was initially used, at about 1500 A.D., the "gases resulting were . . . *waste* gases."[2] The chances are those who tended those furnaces were not aware of the poisonous carbon monoxide they were adding to the air. It is now known that "gases leaving the . . . (iron ore blast) furnace contain more than twenty per cent carbon monoxide."[3] And that one and one half volumes of carbon monoxide to one thousand volumes of air render it poisonous. Informed residents near such a furnace, therefore, would be concerned about the disposal of that "noxious gas."

Fortunately that percentage of carbon monoxide, in the six tons of gases discharged for each ton of pig iron produced, renders the discharged gas valuable for heat and power production. Consequently all iron-producing blast furnaces now are so constructed that the gases produced are mixed with coke oven gas and used for fuel and

[1] Swain, Robert E., "Committee Recommendations to Judge T. D. Johnson." March 24, 1921.
[2] Backert, A. O., "The ABC of Iron and Steel." 1925. Pages 7–8. Penton Publishing Company, Cleveland, Ohio.
[3] Freer, W. T., "Elementary Metallurgy." 1952. Pages 9–10. McGraw-Hill Book Company, Inc.

power. Some of it preheats air for the blast furnace and some serves to power gas engines for the blowers. It is said that, "A single furnace may furnish . . . enough gas to heat its own air blast and have plenty left over to furnish power for a neighboring steel mill or a small town."[4] In other words, "Owing to . . . (the) use (of blast furnace gases it) is now seldom necessary to use any large amount of coal at a . . . (blast) furnace."[5]

It is estimated that there are some three hundred iron blast furnaces in America today. One of these furnaces "may furnish over a hundred million cubic feet of gas per day."[6] Since each furnace runs without let-up for three hundred sixty five days per year it is readily apparent their "obnoxious fumes" add a very considerable to finances from American power.

Sulfur from Smelter Smoke

The chief "noxious ingredients" of the Salt Lake city "air-borne wastes" from the American Smelting and Refining Company smelters were sulfur-containing substances. The order was they were to "be bag-filtered or Cottrell precipitated for removal."

Compliance with that order is well illustrated by the practice of one of the company's subsidiaries. That corporation, in 1951, added added a gas cleaning and processing unit at a cost of $3,750,000. (This was but one in a chain of previous installations since 1921.) More recently they further increased their waste salvaging equipment so the production from that source has been lifted fifty-five per cent. These expansion outlays have always been planned with the expectation that the original cost of construction and equipment will be recovered after a reasonable lapse of time. Presumably, after that "reasonable lapse of time," returns from that source are added to the company's total profit income. Since that plant's seven hundred tons per day production is wholly from smelter reclaimed gases it is evident that for this company the court order "did not cripple the industry."

Fish or Fumes

Preparation of wood pulp requires the removal of lignin from the wood chips.[7] In the sulfite process the lignin is dissolved away from the cellulose of the pulp by an acid sulfite liquor. What to do with this solution poses a problem when its discard into streams kills the fish. When that happens a war is induced between the two industries of the northwest: the pulp producers and the fishermen.

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[4] Deming, H. G., "General Chemistry." 1944. Page 624. Wiley and Sons, Inc.
[5] Backert, A. O., *ibid.* Page 7–8.
[6] Deming, H. G., *ibid.* Page 624.
[7] Hendricks, B. C., "Bisulfite Wood Pulp." School Science and Mathematics. November 1953. Pages 653–5

Since lignin constitutes about twenty-eight per cent of all coniferous woods it is apparent that it, as a fuel, could be an asset. So the filtrate liquor from the chip digester was concentrated from twelve to sixty per cent solid content. It was then burned instead of dumped into the streams. By using magnesium bisulfite solution as the solvent the burning not only produced heat from the lignin but sulfur dioxide, water and magnesium oxide from the sulfite solids. The magnesium oxide was the solid ash and the rest of the products of burning went up the chimney as fumes. If so disposed of they would presently be considered "noxious gases" by the adjoining community. The pulp producers forestalled that by scrubbing the sulfur dioxide out of the chimney fumes and using it with the magnesium oxide ash to make more sulfite to be reused. In addition they discovered that heat from the burning lignin was not only enough to care for the concentration of the lignin solution but provided a bonus of about twice that amount for power use in other parts of the pulp mill. By this "combustion method" of waste disposal there was a salvage of about eighty per cent of the plant's needed sulfite for return to the processing cycle. Here, also, is added finance from reclaimed fumes. And the fishermen are free to fish instead of litigate.

Fluoride Fumes

For these the dairymen offered protest. His suit was based on alleged damage to his herd by fumes from the reduction pots of the neighboring aluminum plant. The judge, however, awarded but $14,000 instead of the $43,000 sought. His explanation was "(Recent) installations of . . . fume control improvements (provide) corrective measures that are effective."[8] This pronouncement marked another industrial success in the control of "noxious gases."

Originally the producers of aluminum metal had assumed that there would be no hazard from escaping fluorides since the solvent, cryolite, which contained the fluorine was not decomposed in the electric reduction of the aluminum ore, its oxide. However, quantity processing soon revealed a loss of that ingredient to the extent of about one tenth ton for each ton of aluminum produced. And further, follow-up discovered that it was also in the gases escaping from the pots. Veterinary doctors had already found the damage fluorides could do to cattle. So the aluminum industry faced a problem. The judge's award publicized that it had made progress in that problem's solution. But they had done more than remove the public menace. They had both reclaimed and re-employed the "noxious gas."

By scrubbing the escaping pot fumes they caught the fluorides

[8] Hendricks, B. C., "Aluminum's Annoying Associate." School Science and Mathematics. February 1955. Pages 149–152.

and by by adding these scrubbings to an alkaline solution of aluminum ore they remade (an artificial) cryolite. This could be used to take the place of that which had been lost. The industry now professes to thus restore as much as eighty-five per cent of that cryolite. This is done by use of the product made by the salvage of those "noxious fumes." For one plant alone this saving amounts to about eight and one half million pounds per year. Thus again is recorded success in fume salvage that is advantageous for both the public and the industry.

Atomic Clouds

Mushroom shaped clouds, symptomatic of atom-bomb explosions, are familiar to others than those resident near Los Alamos and Los Vegas, New Mexico. It is also common knowledge that those clouds also contain "noxious gases." Their mention here is not to record another instance of fume control but rather to note that there is still need for future public concern over "noxious and menacing gaseous" by-products of power and demolition production. In the cases, previously reviewed, success, even in financial advantage, has attended industry's handling of the public's protests. Dare one project that expectation to future encounters with "menacing noxious gases"?

RHEUMATIC FEVER

Rheumatic fever is a disease as crippling as polio and statistically far more prevalent, Dr. Chester M. Kurtz of the University of Wisconsin Medical School told more than 20 Wisconsin physicians attending a three-day post-graduate course on heart diseases.

Dr. Kurtz said rheumatic fever is not only one of the most important diseases in childhood but also "one of the greatest causes of heart disease in adult life." Rheumatic fever hits the 5–10 year age group hardest, he said. Next is the 10–15 year age bracket.

Dr. Kurtz showed x-rays of adult hearts severely damaged because proper treatment of rheumatic fever had not been undertaken when these patients were children. These hearts showed severe injury and great enlargement. "Two thirds of all children in the country with rheumatic fever end with heart injuries," Dr. Kurtz said. "We feel this can be cut almost to zero with early diagnosis and proper treatment." Although the exact cause of rheumatic fever is still questionable, it does run in families, he said. Streptococcus infection triggers an attack.

The best drug treatment in the ordinary case is aspirin, Dr. Kurtz said, at least until the primary stage of the disease is past. Other drugs like sulfa and the new bicillin may then be used as prophylactic agents against recurrent rheumatic fever. The main treatment is "total bed rest until rheumatic infection is completely quiescent. This offers the best chance of eliminating the possibility of heart involvement."

Dr. Kurtz said that a combination of early diagnosis, proper treatment, and prophylaxis to prevent future strep infection is the best the physician can do for rheumatic fever. Dr. Kurtz said April is a peak month for rheumatic fever, with increases again in the late fall when respiratory infections are common.

REMEDIAL ARITHMETIC IN THE REGULAR CLASSROOM*

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It has been a very long time since any competent mathematician has attributed magical qualities to number or our system of notation. The days of old when Merlin or similar wizards confounded their contemporaries with magic tricks relating to number are fortunately long gone. Mathematicians have recognized for many years the fact that our number system is a man made system and therefore logical and capable of being understood and used by man.

Many educators and teachers of arithmetic have held a similar view for years. However, it is unfortunate to note in the history of the teaching of arithmetic that methods of teaching children in this subject area have not always made clear the sense and logic of our number system. Therefore, to many children, number and arithmetic still retained magical qualities. It was not, in fact, until students of the teaching of arithmetic began to stress meaning, insight, and understanding, and began to present number situations in such a manner that children could see sense in what they did that arithmetic began to lose its magical qualities. An illustration of this point can be made in a study of the process of subtraction. It was only when teachers stopped using the equal additions method of subtraction and turned to the more graphic decomposition method that children began to lose their fear of the process. With the use of the decomposition method the borrowed or changed "one" became a sensible symbol and ceased to have the magical quality of appearing out of what often seemed to be thin air.

The work done by mathematicians and educators on the teaching of arithmetic, and the definition of the meaning theory around 1935, helped teachers divest arithmetic of its magical qualities. Since that time the work done by such groups to give the meaning theory practical application in the classroom has rid our schools of an elusive fear and long tolerated ghost—the one relating to the magic of number that stemmed from ignorance and fear.

Now I believe it is time for mathematicians and educators to tackle another "ghostly specter" that, like the former, is taking on undue proportions. The specter and problem about which I speak, openly you will note, is the one concerning those pupils of normal or above normal intelligence found in every classroom who are not

* Read before the Elementary Science Section of the Central Association of Science and Mathematics Teachers, November 25, 1955, Detroit, Michigan,

achieving to capacity in the field of arithmetic. These pupils constitute a group commonly referred to as remedial cases.

We might ponder for a moment the meaning of this all inclusive term—remedial. The dictionary definition of the word implies that when the term is applied to an individual there is a need to remedy something. That is too often true. However, there is another word with the same implication that in my opinion is a little more sensible to apply to those children who are not achieving to capacity. That term is *remediable.* The latter term implies that whatever is in need of remedy is capable of being remedied. The play on words here may seem unimportant, but let me hasten to correct that impression. As the word is used in the literature today it is often construed by teachers to mean slow learner, stupid learner, or a learner incapable of grasping subject matter. This is far from the truth and, therefore, there is a need to clarify such erroneous concepts. About 80% of the children in need of remedial instruction in our regular classrooms are children of normal or above normal intelligence. Many of them are gifted children who are working just at grade level but far below their innate capacity.

It is interesting to note that the percentage of such children in our classrooms today is about the same as fifty years ago. The total number has increased in proportion to our increasing school enrollments, but the percentage of such cases remains the same. We only seem to have more because improved testing programs have helped us isolate such cases more efficiently, and school laws force these children to remain with us for a longer period of time. Fifty years ago such children dropped from school at an early age. Today they plague us because we live with them daily.

Remedial cases are with us today as they were with us 50 years ago. However, we speak openly about them at the present time because we understand the problem much better than we did in earlier years. We know today that a remedial case is not a slow learner, a stupid child, or a dull child. Rather, he is a child who possesses normal or above normal intelligence, but lacks background or understanding in some phase of the instructional program. He is *remediable* and, therefore, capable of being helped. He is no different from many adults because we are all remedial or in need of remedial help in some aspect of our lives. Many of us feel the need of further instruction when we begin to fill out our income tax forms, or follow "do it yourself" directions when building furniture for use in our homes, or try to follow the recipe of a born cook; the type of recipe which reads "a pinch of salt" or "cook until slightly brown."

Care needs to be taken that no stigma be attached to a child in need of remedial help. Care also needs to be taken that no stigma

be attached to a teacher who recognizes that many of her pupils need remedial help. Defects in understanding or mastery in arithmetic cannot be corrected by following an ostrich policy which, in effect, states "out of sight, out of mind." A teacher who recognizes the fact that pupils in her classroom need remedial help should be complimented, because to help a child overcome a deficiency, it must first be recognized as a deficiency.

Once we face squarely the fact that we have children in our classrooms in need of remedial help we are then faced with the problem of what to do with them. Schools, school systems, and teachers are struggling with this problem at the present time.

Many school systems are trying homogeneous grouping. Research studies in the field of individual differences have long indicated weaknesses in this approach. Time after time they have shown that homogeneous grouping tends to work better for educationally retarded children and is not especially effective for the gifted child. Such studies have also consistently emphasized the fact that there are as wide differences in ability in arithmetic and reading among gifted children as among those in our regular heterogeneous classrooms. This is especially true when good teaching is in evidence. Should we then ignore the findings of such studies and assume that achievement in arithmetic is different from achievement in reading and other subject areas? Is this a realistic solution to the problem of remedial cases in arithmetic?

Remedial arithmetic clinics organized in the same pattern as remedial reading clinics are also beginning to spring up. These can help a relatively small number of retarded pupils, but they have never been of much help to the gifted child. In addition it takes large sums of money to equip and staff such clinics. This money usually comes from the developmental program. Can such clinics do the best job for the bulk of our remedial cases?

Many school systems are employing remedial specialists to help with the problem. At present much of their time is being devoted to remedial reading cases and little to arithmetic. Where such specialists are being used to help the regular classroom teacher, they can do much to help with diagnosis and the gathering together of instructional material. However, as usual, the majority of the work and responsibility falls on the regular classroom teacher.

Since under any program the ultimate responsibility for remedial cases will rest with the classroom teacher, why not accept the fact and help that individual do a better job within our present structure. What is so special about remedial instruction that makes it necessary to buy expensive equipment or hire specialists to use remedial teaching techniques? In the last analysis good remedial teaching is simply

good classroom teaching intensified and applied to small groups or individual children. If it is important in our regular classes to give children many experiences with number, then it is also important that children who are not achieving to capacity be given more or less of such experiences depending upon their needs. The nature of such experiences may be different for the gifted or retarded child, but different or not they are still number experiences. We will prevent remedial cases with a good instructional program in arithmetic. Why not help the classroom teacher who administers that program to do a better job to identify, and eliminate difficulties that children have in arithmetic. It is here we need to concentrate our attention, money, and energy in the next few years.

If we feel that the problem of remedial teaching falls within the province of the regular classroom teacher, we must still face the problem of cause and remedy. What are the factors which produce children in need of remedial instruction in arithmetic? Writers in the field devote a large amount of time to trying to isolate the causes. Perhaps this is necessary because we need to know causes so that we can prevent them. Prevention, we would all agree, is the key to having fewer pupils in need of remedial instruction. However, I wish to offer a word of caution at this point to teachers seeking help from the literature. This phase, in my opinion, has been given undue importance in much of the literature. Often, causes that have been isolated are so vague or farfetched as to leave us with the idea that we can do little about the problem, as it requires special help and therefore is out of the jurisdiction of the classroom teacher. But, if we subscribe to the idea of prevention, undue concern or stress about factors or causes of remedial cases smacks of spending too much time "closing the barn door after the horse has been stolen."

Let me, at this point, speak of factors frequently mentioned in the literature and thought of as possible causes of remedial cases. For convenience, I have separated them into four categories; those dealing with the factors relating to the physical, intellectual, personality and attitudes, and educational needs of children. They are not equal in importance, by any manner of means, but do bear some investigation. Classroom teachers should consider them when seeking the cause of remedial cases, but not as seriously as some of the literature in the field would have us do.

Consider first the physical factors; those which relate to eyesight, hearing, muscular coordination and general health. It is true that if a child has deficient vision to the extent that he cannot see to do his work or suffers a hearing loss sufficient to prevent him from profiting from regular instruction, he will in all probability be in need of remedial instruction. This would also apply to a lack of muscular

coordination. However, children with such severe losses of vision, hearing, or muscular coordination are usually not found in our regular classrooms. In most school situations their needs are met with special programs of instruction. Regular classroom teachers need to check remedial cases for physical defects that might have been missed in earlier screening programs, and suggest to parents that such children might profit from medical aid. Beyond this point the regular classroom teacher can do little. Since severe cases are provided for in special programs, we can assume that for children normally enrolled in our classrooms, physical deficiencies are relatively unimportant as a factor in causing remedial cases. Poor general health, on the other hand, often means that a child misses introductory work on a new process. However, the competent teacher will make note of his absence at this time and, when he returns, teach him the process missed. It is only when a teacher fails to do this that poor general health can be considered a contributing factor to a remedial case.

The intellectual factor is also of minor importance if one carefully analyzes children enrolled in the regular classroom. Slow learners or those children who lack the capacity to profit from regular instruction are also placed in special programs early in their school life. The children in our regular classrooms can profit from instruction. Some, it is true, will not achieve at grade level because their capacity is not as great as others in the class and they will be remedial cases. However, the majority of remedial cases in a normal classroom possess the capacity to achieve at grade level, and a large percentage are gifted and should achieve far beyond grade level. These latter cases are truly in need of remedial instruction, and also in need of more attention than they are receiving in our instructional program in arithmetic. Under our present program these children frequently learn in spite of us and not because of us.

Severe emotional problems can create blocks to learning as can unrealistic attitudes. Again, though, a relatively small number of severe emotional problems are found in our regular classrooms, as these children are usually given special help. We do find disturbed children in our classrooms, and their problems are the result of many things such as trouble at home and so on. A good teacher needs to be aware of such problems when they exist and be sufficiently sensitive to children's needs to help them adjust, so that such problems will not hinder learning. The same is true of attitudes toward arithmetic. Frequently parents have had trouble with arithmetic and have grown to fear it because they have never understood it. These fears they all too often pass on to their children. They are easily detected in the classroom if the teacher will watch closely the manner in which children approach work in multiplication, division, and frac-

tions. Such attitudes are also easily detected during parent conferences when the teacher casually mentions that Billy is having a little difficulty with division of fractions. The parent who fosters poor arithmetic attitudes usually responds in this manner in such a situation. "I had similar troubles, and so did his father. Billy does take after his father!" Emotional problems do contribute to fostering remedial cases but not to the extent that we are sometimes led to believe. It is time that we ceased to hide behind them and to realize that many disturbed individuals understand arithmetic.

If the physical, intellectual and emotional factors over which the classroom teacher has relatively little control, are not to be emphasized as causes of remedial cases in arithmetic, what then should be considered? It is obvious that the factors that deal with the educational needs of children must be our first concern. It is especially important that we consider the relationships of these factors to the instructional program. Classroom teachers do have a direct measure of control over the instructional program in arithmetic. Since we continue to have a number of children in our classrooms of normal or above normal intelligence, who do not achieve to capacity, then there must be weaknesses in our instructional program that foster this condition.

If we consider remedial teaching to be nothing more or less than good classroom teaching intensified, then careful consideration of what constitutes a good arithmetic program should help us plan a sound remedial program. An analysis of such a program should point out weaknesses that might foster remedial cases and also suggest possible remedies.

We have long known that a basic goal in a good program in arithmetic is to help children develop the ability to do quantitative thinking. Such a program gives attention to meaning and understanding and teaches arithmetic as a closely knit system of ideas, principles and processes. It gives close attention to the number system and to relationships inherent in the system. This, by necessity, means a continuous and systematically organized course at all grade levels. Systematic as used here does not mean formal but rather planned and provided for in the schedule. Children who achieve to capacity in arithmetic are given the opportunity to take part in such a carefully structured program. They work daily with classroom teachers who know the basic concepts and understandings that underlie the principles and processes presented. These children can expect to understand and use arithmetic effectively because their instructional program leaves nothing to chance.

It is important for teachers to realize that a large number of remedial cases are usually found in schools which have an incidental—

accidental arithmetic program. This condition results, because in such programs basic understandings are too often taught in a hit and miss fashion. If a child misses or never knows about certain characteristics of our number system, he is bound to be hampered in his use of numbers.

It is interesting to note that schools which produce few remedial cases usually have a carefully structured and planned arithmetic program built around a basic text. Most current arithmetic textbooks outline and develop systematically and carefully the basic understandings a child must possess to use arithmetic effectively. It is important that a teacher who is working with remedial cases be familar with what children need to know about arithmetic so that they can build background that is lacking. A reliable and available source for this information is a good textbook. Classroom teachers should not hesitate to consult it frequently for help in knowing what to teach.

Once a teacher *knows* and *knows* specifically the understandings, skills, and number relationships a child should master up to and beyond his present grade level, we can assume that the battle of the remedial case is half won. When a teacher knows what a child should know about arithmetic, it is then possible to determine the depth and extent of his knowledge. It is important, at this point, to reemphasize the fact that a remedial case must be identified before it can be remedied. Let me also emphasize that identification does not mean knowing only that a child is having difficulty and wishing sincerely to help him. Wishful thinking will not help a child achieve to capacity in arithmetic or any other field. Identification means knowing the specific difficulties a child has with every phase of instruction. It means knowing such things as the fact that he lacks the ability to visualize written problem situations or that he has mastered only part of the easy subtraction facts.

How can a classroom teacher identify the children in need of remedial help and isolate their specific difficulties? As mentioned before, the most important thing is to know what knowledge they should possess at their particular level. Then and only then is it possible to find out the depth and extent of that knowledge. This can be done easily by any competent classroom teacher if she will use effectively the tools and materials of instruction, designed for that purpose, and found in most classrooms.

One of the first and most important tools of instruction is the teacher. A teacher's powers of observation are vital to identification of remedial cases. By closely observing the work of children, teachers can readily detect those individuals who use inefficient methods to attack problems, or fail to arrive at correct solutions because they

lack understanding or skill in a particular process. All a teacher needs to do to get such information is to watch children at work, check written work with attention directed to types of errors, and on occasion ask children to think out loud.

A second source of information is the standardized test results. So often, achievement tests are given and then carefully filed away in the principal's office. Many achievement tests can be used for diagnoses, if a teacher will take time to analyze specific test items and make a careful list of the errors children make. A check on earlier tests will usually reveal if errors are new or just persistent. If an error is new, usually direct teaching on the point will overcome difficulties very quickly. If it is a persistent error, then perhaps it will be necessary to go back to beginning work, and do a thorough job of reteaching. Careful analysis of tests will also indicate those children who possess a good understanding of what has been taught and therefore can be freed to do other kinds of work.

A third available source is the arithmetic textbook. Every good text includes inventory tests, achievement tests, and diagnostic tests. In addition, the first sixty to eighty pages of most textbooks from the fourth grade on, are usually devoted to testing, reviewing and enlarging upon understandings, skills, and processes already presented. In essence this is remedial teaching. The teacher's manual also gives suggestions for further diagnosis. Most arithmetic textbooks published within the last five years are very useful teaching tools. We need to learn to use them more effectively as they provide much help for remedial teaching. However, one must recognize that in order for a classroom teacher to find remedial aids she must sometimes read between the lines in a text or use just parts of lessons. As yet, few textbooks label pages or designate certain sections as those to be used for remedial work. Perhaps the erroneous meanings that have unfortunately grown up around the word remedial make textbook authors hesitate to admit openly that such cases might exist, even in systems that adopt their particular textbook. When teachers and educators apply the term remedial to gifted, as well as educationally retarded children in their classrooms, perhaps this condition will not exist.

We have known for a long time that reading is an active and not a passive process. This is true whether we try to read symbols that stand for words or symbols that stand for quantity. When a child works with symbols of any kind, letters or numbers, he is working with abstractions. If we fail to help him develop adequate meanings for these abstractions, so that he is freed to use them to solve quantitative problems and bring order to his world, then we create a remedial case.

In view of these facts, it is important that teachers not only know what to teach but how to teach. Certain basic principles of method are stressed in all good arithmetic programs. A knowledge of principles is especially important to classroom teachers who recognize that many of their children are not working to capacity because method has a direct relationship to the degree and quality of understanding children attain in arithmetic.

One principle of method that is given great weight in the instructional program today pertains to the use of concrete and semi-concrete materials to give meaning to arithmetical facts and processes. This emphasis is correct and good because we know that concrete objects, when used correctly, help children visualize number situations and give meaning to abstract symbols. However, the accumulation, construction, and display of such materials is becoming too important in some arithmetic classrooms. Too much instructional time is being devoted to such purposes. Since the production of such materials on a national scale has become a lucrative business venture we find a tendency on the part of producers to claim unusual results for these devices. In some cases, we could almost believe that purchase alone cures all arithmetic ills. If this seems to be an overstatement of fact, just count the number of pages that are devoted to explaining to teachers, either how to make, or where to buy these devices in some textbooks, teachers' manuals and professional books and journals.

Some place along the line we have tended to forget the fact that relationships, generalizations, concepts, and abstract ideas of number do not necessarily become clear just because we have concrete objects in our classrooms. The mere possession of concrete objects such as straws, bundles of sticks and so forth, does not, for example, make them countable. It is only when children have discovered that objects can be organized and grouped in such a manner that their total quantity can be determined by a simple process that we find their use meaningful. In other words, the possibility of counting objects occurs to children who have learned to count.

If a teacher only accumulates concrete objects and does not use them to give meaning to arithmetic facts and processes, her instructional program will produce many remedial cases. Over exposure to the use of concrete materials and a blanket policy of forcing children to use them at every stage of instruction prevents early use of abstract symbols by gifted children and creates an over dependence upon objects for the retarded child.

On the other hand, too little use of concrete objects or failure to use them in strategic places, means that a valuable method of helping children visualize a quantitative situation is being neglected. Also

failure to teach gifted children to use semi-concrete objects such as graphs and charts will prevent them from mastering an effective technique to use when organizing or presenting quantitative data. Classroom teachers concerned with remedial instruction should consult textbooks and manuals carefully so that they will use such devices in the most efficient and effective manner. Also teachers should learn to close their eyes and ears to somewhat wild advertising about such devices. We need to be careful that use of concrete materials in arithmetic does not take over the instructional program as use of the picture clue has tended to do in primary reading.

To use concrete materials effectively with remedial cases we must consider another basic principle of method; the principle which in effect states that children should be given the opportunity to learn through experience. These two principles go hand in hand. Just as the physical presence of concrete objects will not insure learning in arithmetic neither will the mere amassing of number experiences insure learning. All teachers of arithmetic need to recognize that meanings have their origin in experiences, but at the same time they must recognize that the type of experience determines the clarity, depth, and correctness of the meanings achieved.

The child in need of remedial instruction—retarded or gifted—will not build number meanings simply by being exposed to vague number experiences. I am speaking here about lessons taught in arithmetic classrooms which are erroneously labeled number experiences. Experiences of this type often involve physical activity because for some reason or other we tend to think of movement when we think of experience. We forget that one of the most worthwhile experiences children can have is to think, and this can often be done best in a quiet and relaxed classroom.

Perhaps I can illustrate this point through a situation involving the idea of division. A good teacher usually decides when working with remedial cases on a concept such as this that they need more experiences with the idea. She knows through diagnosis when the majority of the class have a fairly good understanding of the idea. However, she also knows that four class members lack any understanding while four others understood the idea long before it was presented in class. This well meaning teacher of 38 pupils has read somewhere that children should be given the opportunity to learn through experience. However, when she planned today's lesson, she neglected to read her manual carefully or actually read only enough to find out that it suggested she set up sixteen chairs at the front of her classroom and give the children an opportunity to divide them into equal groups. Now experience in this teacher's mind has a direct

relationship to activity and you will remember she has 38 active children in her classroom. What then does she do? She suggests that the eight remedial children, four retarded and four gifted, find sixteen chairs and arrange them at the front of the classroom. She is careful at this point to allow the four gifted children to arrange the chairs in a neat row because she knows the retarded children are apt to do a sloppy job and besides they can gain much from watching more able pupils work. She also knows that she doesn't have sixteen free chairs in her classroom and will need to borrow from other rooms. This presents no problem though because she knows retarded children need many experiences with number and certainly hunting up extra chairs will require them to count and add to get a sufficient number. At this point she doesn't concern herself with the remainder of the class. After all chairs are familiar objects and concrete in nature and therefore they will naturally be interested in this experience. When the chairs have been arranged the teacher then asks, "How many fours in sixteen, how many twos, and how many eights?" A gifted child is then asked to arrange the chairs in these groupings. The experience is then completed and the teacher can relax. She has taken care of individual differences, through the use she has made of the gifted and retarded children and she has provided an experience with number. One might ask at this point, "What has been learned about division?" Actually less than nothing because as mentioned before this teacher did not read the manual or think through the lesson. Therefore, she forgot to note that the manual suggested that after the pupils arranged the chairs certain questions be asked to direct their attention to the idea of division. Also that after they mastered the idea it be divorced from direct experience and be applied to number situations involving different amounts, values and ideas. The manual also suggested that perhaps the teacher might like to break her class into groups at this stage and assign different practice exercises. However, none of this was done because the teacher either neglected to read the manual or if she did the procedure was not made clear. If this example seems unreal, I suggest that those who doubt the accuracy visit many different classrooms where children are being given number experiences.

Remedial cases do need many direct and indirect experiences with number. However, our teaching materials need to be more specific on this point, so that this important principle of method is applied effectively in our arithmetic classrooms. If our materials do the job adequately then we need to look at our in-service work to see if we are training teachers in how to use these instructional materials.

Too many teachers feel that playing store for example will teach children how to add, subtract, multiply and divide simply because it is an experience which involves the use of number.

It would be possible at this point to go right down the line and name all of the basic principles of method which affect the instructional program in arithmetic. It would also be possible to point out the manner in which misunderstandings and misuse of such principles of method can cause remedial cases in arithmetic. The relationships which exist between the instructional program in arithmetic, the materials used, and the methods of presenting ideas, concepts and skills are vital to the number and type of remedial cases found in a school.

Many remedial cases in arithmetic could be prevented or remedied if teachers would only take time to examine closely their materials of instruction and sharpen their teaching techniques. Specifically teachers need to (1) know what concepts, understandings, and skills have been presented up to and including their grade level, (2) examine and use carefully materials such as the tests provided for diagnosis in the textbook or by the school system, (3) plan specific lessons built around basic principles of method to overcome diagnosed difficulties, and (4) keep records of the progress made under such a program so that results can be evaluated by the future instructors of remedial children.

Suppose we apply these techniques to a hypothetical case to illustrate what any classroom teacher can do to help a child with normal intelligence overcome difficulties in verbal problem solving. We shall assume that this child's difficulties are due to omissions in the educational program and are not caused by emotional, social, or physical problems.

The first thing a teacher would do in such a situation would be to make certain that she is familar with the knowledges, skills, and understandings a child should possess at his instructional level. She will get this information either from her own educational background or by carefully reading pertinent material in the textbook and manual.

As a second step she would examine school records and test results and items to determine if the difficulties are persistent ones. She will also administer diagnostic tests found in the textbook or provided by the school to determine specific difficulties. A careful record should be kept at this point.

The third step will consist of acquainting the pupil with his specific difficulties in such a manner that he faces them and also realizes that with the teacher's help and hard work on his part he can hope to overcome them. The teacher will then turn to the basic text and any

other available source, such as a course of study, to find lessons that will help a child overcome specific difficulties. Many times she will not find such lessons and will need to develop them on her own. However, one way or another she must re-teach every step and tackle every point of misunderstanding. Nothing must be left to chance or omitted.

The fourth step would be to keep accurate records of every lesson. These records must be examined frequently to see that nothing is being omitted. They will also help the teacher plan a careful testing program at various stages of instruction. It is usually not possible to complete such work in one semester. Therefore the teacher must send these records with the child when he goes to another classroom. If this is done the next teacher can continue the work without loss of time.

The procedure outlined can be followed by any classroom teacher willing to spend the time and energy required. Since most teachers have large classes of children today these techniques must be applied to groups of remedial children rather than to individual children. However, they can be used effectively with both. The most important thing to remember is that their application will help to reduce sharply the number of remedial cases found in our schools.

THE SUPERIOR PUPIL

THE SUPERIOR PUPIL IN JUNIOR HIGH SCHOOL MATHEMATICS. By Earl M. McWilliams and Kenneth E. Brown. Office of Education Bulletin 1955, No. 4. 57 pages. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 25 cents.

What are some of the most promising practices used in the junior high school to provide for the educational needs of talented youth? What administrative procedures are used to identify these pupils? What enrichment techniques have mathematics teachers of heterogeneous classes found especially useful in teaching the superior child? These and many other related questions are discussed in *The Superior Pupil in Junior High School Mathematics.*

To secure data for this new publication the authors visited classrooms in 140 junior high schools from Maine to California. Schools were selected because of their reported educational provisions for the superior pupil. The classroom provisions for the superior pupils in these selected schools are described. The use of class activities such as mathematics clubs, contests, various conferences, etc. are discussed. Ways of identifying superior pupils are presented.

School administrators, curriculum directors, and supervisors will find the organizational procedures for the superior pupil of special interest. The promising instructional practices will be especially helpful to the classroom teacher.

WHAT ARE YOU TEACHING?*

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Because of the traditional position of mathematics in our educational program this has actually been an important question for many years. In the "good old days," however, the question was given little serious consideration. At that time it seemed to be generally agreed that, if one wanted to be educated, mathematics was a must. The backbone of education was symbolized by the 3 Rs. In this era what mathematics was taken apparently was not a paramount problem even though it should have been. The reasons for this attitude, I think, are fairly obvious. Because at least the basic parts of the subject were practical—at least paraded under that guise. Further, mathematics was supposed to be logical so if you took courses in mathematics you would learn to reason and think more logically. Also for many students mathematics was fairly difficult so it was not easily mastered. Hence, the subject was good mental discipline. It is not surprising that in this educational climate teachers of mathematics went merrily on their way with little thought to the question of what they were teaching. For individuals who dislike change and who dislike being mentally disturbed this must have been a delightful era in which to teach mathematics. A teacher taught what he had been taught, thus perpetuating a prescribed cycle of knowledge.

Perhaps the first serious efforts in this country to answer critically the question, What are you teaching?, occurred when it became the accepted pattern for almost everyone to go to high school. At this point our high schools ceased to be thought of as preparatory schools for the colleges and universities. Actually they probably never were, if one were to use as a criterion the per cent of high school graduates who went to college. Now, however, as the number of students going to high school increased rapidly, the number who apparently could not cope with the abstractions of algebra and geometry seemed to increase at least as rapidly. This situation probably would not have caused so much concern had it not been for the fact that the going to high school was no longer a voluntary action. Society was insisting that everyone have a certain minimum number of years of schooling. This made problems. I am sure you are well aware of this situation. Because of these circumstances the place of mathematics in the curriculum was viewed critically and the question, What are you teaching?, was asked even more critically. I do not believe that anyone

* Read at the Mathematics Section of the Central Association of Science and Mathematics Teachers, Detroit, November 25, 1955.

can say that the teachers of mathematics did not defend the subject with enthusiasm and conviction nor that they have not tried to find and introduce courses into the curriculum which would fit the needs and the mathematical ability of all the students. Even so, it is apparent from the numerous articles appearing in the various journals that we are still looking for more adequate answers, hence not really satisfied with our proposed answers.

All of this critical evaluation had very little impact, however, on the program in mathematics for the college bound except for attempts to introduce unifying ideas such as the function approach. This situation was probably because the colleges and universities made no changes basically in their entrance requirements since their programs appeared to be well stabilized other than minor fluctuations from compartmentalized teaching of the subject to integrated courses and then back. There was very little variation in content. Rather, the variations were mostly in the way that the topics were coordinated.

The college program was fairly satisfactory because what was included did not appear to be too important. The reason for this situation, I believe, is fairly evident. Very little mathematics was being used in psychology, the social sciences, and the other related areas. Of course some statistics was being used. To these groups though it made little difference what was included in the basic college courses in mathematics. Even where mathematics was the foundation and building blocks of the subject such as in engineering and science (physical), the question of what was being taught was not often asked. These areas required that the student take the basic courses through the calculus but used this mathematics in their courses sparingly. How true this situation was is strikingly reported by C. V. Newsom.[1] "A short time ago I looked over a textbook on physical chemistry that I studied nearly thirty years ago. This course was taken in the latter years of my college career, but, it seems impossible to believe, there is not a single integral in the entire book. In my total undergraduate program of science and engineering I have no recollection of using any mathematics other than the simplest algebra and trigonometry. I can still remember my surprise as a graduate student when I found some practical uses for the definite integral."

Now the colleges and universities are facing the problem of trying to educate and train ever increasing numbers of students. The number reaching college age each year is increasing as is the per cent going to college. At the college level this makes a problem similar to that which the high schools faced some years ago. For students who need very little more mathematics than they had in high school to

[1] C. V. Newsom, "Some educational problems of significance to engineering college," *The Mathematics Teacher*, April 1955, p. 197.

complete their college program the generally proposed solution is a terminal course which introduces some statistics and some other topics such as logic, number theory, etc. For this group the problem is essentially one for the colleges to solve, so we shall by-pass it. In this connection it should be mentioned that another approach to this whole problem has been advocated recently. This proposal is that a universal course be developed that would be suitable for all college students at the freshman level. Those of you who read the journals, I am sure, are aware that such a text is being written. If this is the ultimate or accepted answer, then the content of this course will be of interest to all teachers of mathematics, if we are to have a well coordinated program.

Since an increasing per cent of your graduates are going to college, this makes many more of our problems mutual ones. Further, World War II furnished the impetus for a more intensive use of all of our knowledge and the rapid expansion of its frontiers. With each forward step the need for more advanced mathematical training is not only evident, it is necessary. Hence, if we are to give our capable engineering and science students adequate training in mathematics and the sciences we must require that they stay in college longer or we must accelerate their program. For these students, I think, there can be only one answer. We must arrange our programs so that they can start calculus at least by the second semester of the freshman year. This is what makes the question, What are you teaching?, so important for all of us today. No doubt the major changes will have to be made by the colleges and universities. Here it will mean a careful evaluation of every topic as to its importance in the useful mathematical education of the students. I am sure this means that many time honored topics will be deleted and new topics included such as mathematical logic, careful introduction of the number system, sets, algebra of sets, etc.

However, for such a program—the introduction of calculus in the freshman year and the completion of the basic concepts of differential equations by the end of the sophomore year—to be successful means that the colleges and universities are going to have to depend even more on our secondary school teachers of mathematics. We will have to depend on you to help your students get a thorough mastery and a sound understanding of the fundamental techniques of algebra and trigonometry because the basic work in analytical geometry will have to be included in the first semester in college. To assist you some colleges are substituting trigonometry for admission instead of solid geometry. Where this is done students will probably be admitted with a deficiency but I am certain that this procedure will not be encouraged even though a very capable student could complete the

two years of basic mathematics on schedule. For the less capable student and the one who has not adequate training the sequence will require at least five semesters to complete.

The scientists and the engineers are not the only ones who are involved. The increased use of statistical theory, linear programming, decision making, card programming, digital and analogue computers, and many topics from advanced mathematics in the areas of industrial management, economics, sociology, psychology, etc. means that the students studying these subjects will need more mathematics and sooner than it has previously been possible for them to take the advanced courses. Consequently, the people in these areas are beginning to ask the question, What mathematics are you teaching?

Last but not least of those asking the question are the mathematicians, themselves. Here there has been a complete revolution from twenty-five years ago when virtually the only opportunity available to those interested in mathematics was in teaching and where there was an oversupply to today when the needs of governmental agencies and industry are probably sufficient to absorb our entire output of majors in mathematics at all levels. Not only does it appear that they can use all who are interested in such positions but they are paying such attractive salaries that many of our most capable prospective and in-service teachers are leaving the teaching profession even though they may prefer to teach. They do not feel that they can afford this luxury. We are indeed fortunate, however, to have so many who find the less tangible rewards that accrue to teachers more satisfying. But for all who major in mathematics, wherever they make seek employment, the demand is the same as in the other areas. They must know more mathematics than majors in the past have needed to know.

Thus we see that the question of what mathematics is being taught is no longer a question of limited interest because almost every area of learning now has a vested interest. Hence, whether people are in academic work, business, or government they are vitally concerned.

Just what mathematics are you teaching? Have you tried to teach some modern mathematics in any of your classes? Here is an area where I think some of you should become leaders. Much has been written and many talks have been given advocating the introduction of some of this material into the high school program. I am sure that we agree that such topics are probably not suitable or desirable for everyone taking mathematics in high school. However, for the average and better than average students, I believe, it is time to try some of it. Answers must be found as to whether it is actually feasible and/or profitable. In order to get answers, carefully designed and administered experiments must be made to learn how successfully

such materials can be studied. We must learn more about the students' levels of mathematical maturity. You could help by collaborating on such experiments. These are important questions in terms of future curriculm and they can not be answered or resolved by logic, ultimatum, persuasion, or wishing.

However, without any radical changes in your program, I think that there are ways in which you can help prepare your students for some of this more abstract mathematics they will soon be taking if they go to college. One of the basic concepts in mathematics is the nature of a mathematical system. For our purpose, it is sufficient to state that a mathematical system consists of undefined terms, definitions, axioms, and theorems. When you get to geometry most of you give this structure concept a certain amount of emphasis and consideration. Why do you wait until you get to geometry? Why not do this in elementary algebra? All the basic elements are there and they can be introduced quite neatly if you do not try to make the presentation too rigorous. The question of rigor doesn't seem to bother too much in geometry. Quoting again from C. V. Newsom[2] "I happen to believe in good mathematics, but in some class rooms the attempts that are being made in the direction of greater rigor completely ignore the student's level of maturity and his ability to comprehend. After all, there is no such thing as absolute rigor; it is a function of a person's maturity and past experience." Consequently, I would not advocate nearly as much elegance and precision as a sophisticated mathematician might prefer. However, if use is made of the definitions and axioms, then algebra takes on added significance and the elementary parts appear as a coherent structure. To me this is a much more unifying and satisfying approach then the function concept and certainly less involved than the application in geometry.

Let me illustrate. I would begin by agreeing that we must have a set of rules that at the start are meaningful when applied to positive integers. After a consideration of examples the students will no doubt agree to the common axioms dealing with adding, subtracting, multiplying, and dividing equals by equals with the proper restriction on subtraction and division. Along with these axioms must be included the one which equates quantities which are equal to the same quantity. These should be followed by the associative and commutative axioms for addition and multiplication together with the distributive axiom for multiplication.

After it had been agreed that these axioms work for the positive integers, I would propose that we now use them as a base of operation.

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[2] C. V. Newsom, *ibid.*, p. 196

I would note further that we have in no sense proved the axioms. All that has been done is to show that they are convenient axioms. I would then propose that we see where they lead us if we apply them to the quantities 0, 1, a, b, c, . . . , where we define

$$a+b=c$$

$$ab=e$$

$$a-b=c, \quad \text{provided } b+c=a \text{ (Definition of subtraction)}$$

$$a\div b=c, \quad \text{provided } bc=a \text{ (Definition of division)}$$

$$a-0=a$$

$$(a)0=0 \quad (a \text{ any definite number or quantity.})$$

$$a-a=0$$

$$(1)a=a.$$

It is understood that all operations yield elements of the set. Of course these are not all the definitions that are needed nor has any attempt been made to reduce it to the minimum number. I believe, however, that is a set of axioms and definitions that can be understood by students taking elementary algebra.

Now negative numbers arise from a consideration of the definition of subtraction. Thus, we defined $a-b=c$, provided $b+c=$a. That is, a is the sum of b and c so that, if these quantities are positive integers, a necessary restriction is that a must be greater then b. This naturally raises the question as to what happens if we do not make this restriction. I believe it will be apparent even to first year high school students that either the restriction can not be removed or else something new must be added. Historically this was a big jump in the development of mathematics. As you know, it was not easy. This should be pointed out to the students. It should then be clearly stated that this restriction on subtraction was removed (can be removed) by defining the quantities -1, -2, -3, $\cdots$ which have the property that

$$a+(-a)=0, \text{ and}$$

$$b-a=-(a-b) \quad \text{when} \quad b<a.$$

This leads to the necessity of distinguishing between the use of a dash to indicate the operation of subtraction and a negative number. This double use of the plus and minus symbols doesn't make things easier for the beginning students. That $6+(-2)$ and $6-(+2)$ are both equal to 4 is certainly a bit confusing.

We are now in a position to determine what the value of $(-2)+(-3)$ is. Let the sum be x. Then

$$(-2)+(-3)+2+3=x+2+3=x+5$$

by application of the proper axiom. From the definition, the left member is zero, whence by definition also x is -5. This leads us neatly and directly to the rule for adding signed numbers with like signs. Next consider a sum such as $3+(-2)$. If x is the sum, then

$$\begin{aligned} 3+(-2)+2&=x+2\\ 3&=x+2\\ 3-2&=x. \end{aligned}$$

Thus we see that adding a negative number yields the same result as subtracting the positive number of same numerical value.

What do you do when you get to the question as to what the product, $(-a)(-b)$, is? With elementary students I would simply define the product and also the product of a positive and a negative quantity. I would then proceed to show that these definitions—often called rules—are necessary if the distributive axiom is to be preserved. Of course you can show that these rules are also useful in certain practical situations. However, this is no proof of the rule. The important point to make is that definitions are made which preserve our original axioms. It should be observed next that once the definitions for the multiplication of signed numbers are stated then the rules for division follow at once as a consequence of the definition of division. Thus, $6\div(-2)=-3$ because $(-2)(-3)=6$.

Again, $3a+4a=7a$ because we have assumed the distributive axiom. It is not enough to say this and then give the rule. You should actually write it out

$$3a+4a=(3+4)a=7a$$

again and again until the students understand the reason for the rule—

To combine like terms, combine the numerical coefficients and multiply the result by the common literal factor.

Multiplication and the reverse operation, factoring, also follow in algebra from the distributive axiom. Thus,

$$\begin{aligned} (a-b)(c-d)&=(a-b)c-(a-b)d\\ &=ac-bc-ad-bd \end{aligned}$$

by applying the distributive axiom twice.

Do you show why

$$(3a)(7b)=21ab?$$

That is, that

$$\begin{aligned}(3a)(7b) &= 3(a7)b && \text{by associative axiom}\\ &= 3(7a)b && \text{by commutative axiom}\\ &= (3.7)(ab) && \text{by associative axiom}\end{aligned}$$

Whence

$$= 21ab$$

If you do show each of these steps in several examples, the rule for the multiplication of monomials doesn't appear to develop out of thin air or no air at all.

Also, do you show that fractions must be introduced to remove a limitation on our definition of division just as negative numbers and zero were introduced to remove an analogous restriction on subtraction? Thus, by definition $6 \div 2 = q$, provided $2q = 6$. As a consequence we see that q is an integer, if and only if 2 is a factor of 6. If our number system is restricted to the integers then there are many quotients which cannot be obtained. In general $b \div a = x$, provided $ax = b$. If a is not a factor of b we can proceed only if we introduce a new number, b/a, which we call a fraction. From our definition this new number is subject to the rule that $a(b/a) = b$, so that by definition b/a is the value of x, the quotient. These new numbers now remove all restriction on division except for the case where $a = 0$. We must exclude $b \div 0$ and symbols such as $b/0$ because they are meaningless. For, assume $b \div 0 = q$, then $0q = b$. But one of the defined properties of zero is that $0q = 0$, when q is any definite number. We are thus led to the inconsistency, $0 = b$, which cannot be removed. Or consider the equation $0 \cdot 2 = 0 \cdot 5$, which is certainly a true relation. Dividing both members by zero, we obtain $2 = 5$, which is quite absurd.

Exclusion of division by zero is not a serious restriction but it does introduce some problems. Thus, in trigonometry we define tan $A = y/x$. From the general definitions of the functions we obtain when $A = 90°$, tan $90° = y/0$. Actually then tan 90° does not exist, because $y/0$ is meaningless. However we find in many texts the statement, tan $90° = \infty$. Although this is a perfectly good mathematical statement I think it should be introduced and used with extreme care. When you use it be careful to emphasize what you mean by that particular shorthand notation. It says that the tangent ratio for ninety degrees does not exist and further that as a approaches ninety degrees the tangent ratio increases without bound. The symbol, ∞, does not represent an algebraic number, hence is not subject to the ordinary rules of calculation. Another difficulty occurs in

cases such as $1/(n-1)-1/(n-1)$. This difference is zero if n does not equal one, but is meaningless if n equals one.

Once fractions are introduced we must define the basic operations consistent with our fundamental axioms. Thus, we define

$$\frac{a}{b}\cdot\frac{c}{d}=\frac{ac}{bd} \quad \text{(The product of two fractions)}$$

$$\frac{a}{b}=\frac{c}{d} \text{ provided } ad=bc. \qquad \text{(Equality of two fractions)}$$

This definition of the equality of fractions offers one method of introducing the fundamental principle, that the value of a fraction is unchanged if the numerator and denominator of the fraction are multiplied or divided by the same quantity, provided the quantity is not equal to zero. By application of these definitions and the axioms, we obtain the rule for the addition of fractions. For example, $1/2+1/3=3/6+2/6=(3+2)(1/6)=5/6$. This makes it evident that, if fractions are to be combined into a single fraction, the denominators must be made the same. In the same manner we get the general rule

$$\begin{aligned}\frac{a}{b}+\frac{c}{d}&=\frac{ad}{bd}+\frac{bc}{bd}\\ &=(ad+bc)\ \frac{1}{bd}\\ &=\frac{ad+bc}{bd}\,.\end{aligned}$$

Consider next the divison of fractions. Let Q represent the quotient

$$\frac{a}{b}\div\frac{c}{d}\,.$$

We can write

$$\frac{a}{b}\div\frac{c}{d}=Q$$

provided

$$\frac{c}{d}\,Q=\frac{a}{b}\,.$$

Multiplying equal quantities by equal quantities

$$\frac{d}{c}\left[\frac{c}{d}Q\right]=\frac{a}{b}\cdot\frac{d}{c}\cdot$$

Whence

$$Q=\frac{a}{b}\cdot\frac{d}{c}\cdot$$

From this general relation we may state the rule—to find the quotient of two fractions, invert the divisor and multiply.

In the foregoing discussion, I have tried to illustrate how one can show the logical development of the basic rules of algebra from a set of assumptions. At the same time I have tried to indicate how negative numbers and fractions must be introduced if our axioms are to hold without restriction. This extended number system is, of course, the domain of rational numbers. These numbers possess the property that the operations of addition, subtraction, multiplication, and division with these numbers always give a rational number. Such a domain or set is said to be closed with regard to these operations. When this happens the set is called a field. This process of enlarging a domain is an important example of the generalization process characteristic of mathematics.

Thinking in terms of generalization, do you try to get your students to think in terms of other generalizations that are inherent in elementary algebra? For example, that mathematically $z=kxy$, $f=kma$, $E=IR$, $T=kpv$ are all the same? In each case, regardless of the physical phenomena involved, the relation expresses the fact that three quantities are so related that the product of two of the quantities is proportional to the third. Similarly, that

$$\frac{1}{z}=\frac{1}{x}+\frac{1}{y},\qquad \frac{1}{f}=\frac{1}{f_i}+\frac{1}{f_0},\qquad \frac{1}{R}=\frac{1}{r_1}+\frac{1}{r_2},\quad \text{and}\quad \frac{1}{c}=\frac{1}{c_1}+\frac{1}{c_2}$$

all express the same relation between three quantities.

Equations also offer an excellent opportunity to introduce some good mathematics along with the development of the techniques for solving them. For example, if x denotes a number, then an expression such as x^2+3x is a number. The statement that this number is 10 is an equation. Thus, $x^2+3x=10$ is an equation. Of course, you realize that this statement is not necessarily true. As a matter of fact you know that it is true only under certain conditions, when $x=+2$, and when $x=5$. Hence, it is a conditional equation, while $(x+1)(x-1)=x^2-1$ is true for all x, so it is called an identity equation. The relation

$$\frac{x^2-25}{x+5}=x-5$$

is true for all x except $x=-5$. Or, one can say that it is true for all x for which both members are defined. In general, this is what is meant by an identity equation.

Let us consider the solution of the equation $5x+4=3x+8$ in the following manner. We can say, if $5x+4=3x+8$, then subtracting the equal quantity, $3x$, from both members makes both members equal and we write, $2x+4=8$. Similarly, subtracting 4 from both members we obtain $2x=4$. Dividing both members by 2, we get $x=2$. Thus, we have reasoned that, if $5x+4=3x+8$, then $x=2$. It is, of course, apparent that it does not follow from this reasoning that $x=2$ is a solution. We are merely guaranteed that if $5x+4=3x+8$, then $x=2$. To determine if $x=2$ is a solution we must prove the converse theorem, i.e. if $x=2$, then $5x+4=3x+8$. This can be done readily by verifying by substitution, and, also, by showing that the steps we performed in obtaining $x=2$ are reversible. Hence, in solving this equation, it has been necessary to prove a theorem and its converse. This permits us to say that $5x+4=3x+8$, if and only if, $x=2$. If the student can follow this reasoning, then he can understand why it is necessary to check a solution. In addition this introduces another important mathematical concept, the necessary and sufficient condition—if and only if.

With these illustrations I have tried to indicate why I think that elementary algebra is the best place to start teaching some good mathematical thinking along with the development of algebraic manipulative skill, which is also most essential. The examples which have been used are fairly isolated but should suggest procedures that can be used all through elementary algebra to give it continuity. What are you teaching?

FELLOWSHIPS IN TEST CONSTRUCTION AT PRINCETON

Two associateships, one in Humanities and one in Mathematics, are being offered to give interested members of the teaching profession an opportunity to become familiar with test construction procedures and give members of the Test Development Division staff an opportunity to maintain contact with the problems and current practices in the schools. Associateships are for a period of 2 months (July 2 to August 31, 1956) and carry a stipend of $700 and reimbursement for round-trip transportation to and from Princeton. Applications must be submitted by March 20, 1956. All inquiries should be addressed to

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THE IMPORTANCE OF HELPING PROSPECTIVE TEACHERS TO USE FACILITIES OUTSIDE THE LABORATORY AND TEXTBOOK*

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Introduction

A topic such as this one may cover many areas. Yet, analyzed to its point of focus, it deals obviously with the values of direct experiences and those of vicarious as they are related to the training of prospective science teachers. Any discussion of this topic may well degenerate into a reiteration of oft-repeated platitudes and cliches of "how nice it is to provide direct experiences for children." Without doubt every teacher has listened many times to speakers who have stressed this latter point, namely that it *is* important to provide direct experiences. Yet despite such emphases it is well known that direct experiences occupy less than one-tenth of the time spent in the typical classroom—the rest being devoted to vicarious. It would seem therefore that this discussion should do more in order that classroom practice may be changed for the better. Hence, the emphasis here will be on "*why* the use of direct experiences should be taught prospective teachers." In other words, "Why do direct experiences increase learning effectiveness in the sciences."

Some Basic Assumptions and Limitations

In evaluating the relative merits of direct and vacarious experiences, there are of course a number of assumptions and limitations that must be considered. In training the prospective science teacher, certain of these need to be emphasized, among them the following:

1. *Direct Experiences Cannot Completely Supplant Vicarious*

It is well-known that students develop short-term curiosities and long-term interests in many areas in which direct experiences are not practicable. No student can experience directly the temperature of the sun, the reactions within an atomic pile, the process of photosynthesis within a leaf, or the formation of igneous or sedimentary rock. Such experiences must be vicarious.

Further, we live in a cumulative technology, not a culminative one. This implies that learning experiences are expected to contribute to the advancement of knowledge, not merely to the absorption of the past. Thus we cannot expect students to learn by living again all

* An address given at the program of the Mid-West Conference on The Education of Teachers in Science, Indiana University, April 8, 1954, on the University Bradford Estate, Martinsville, Indiana.

the experiences of their ancestors. It is far more efficient to have them receive vicariously in a few days the key ancestral experiences that can be learned directly only in centuries. The time spent with the direct variety of experience may then be devoted to learning the contemporary, and in searching for new truths.

2. *There Are Many Reasons for Providing Direct Experiences*

One could discuss the values of direct experiences from many approaches, namely, instructional, curricular, philosophical, and psychological. It was obvious therefore that some limitation would have to be made. For this discussion, it was decided to explore the approach that is taken least frequently, the psychological.

THE PSYCHOLOGICAL APPROACH TO DIRECT EXPERIENCES

1. *The Role of the Neural Mechanism*

No one knows *exactly* how the human brain functions. Yet over the past years, sufficient evidence has accumulated to support several generalizations about its operation. The sensations or experiences that the sensory organs receive may be either direct or vicarious (symbolic). For example, if one sees a horse, the experience is direct. However, if one sees the word "horse," or hears the word "horse," the experience is vicarious (symbolic). In the case of the direct experience, the response made to the horse follows more or less directly the activation of the respective sensory area in the brain. In the case of the vicarious (symbolic) experience, the sensations first activate the appropriate sensory area, are then shunted to the appropriate memory and associative areas. Here the vicarious experience is associated with a trace of a previous direct experience.* The response then follows. This may be diagrammed as follows:

Direct: /HORSE→RESPONSE TO HORSE
Vicarious: HORSE→ASSOCIATION WITH AND/OR MEM-/ORY OF, HORSE→RESPONSE TO HORSE

The behavioral mechanism in reacting to a horse obviously involves fewer steps when the experience is direct than when the experience is vicarious. The direct experience therefore requires fewer operational functions of the brain mechanism.

There is of course another problem involved. In order for a proper response to be made to a vicarious experience, the subject must first recognize the symbol, then make the attachment in his brain to the correct memory trace. It is possible of course to become confused by the symbol and fail to make the proper attachment. Obviously

* For this paper the description of the process has been oversimplified. However, the general analogy is correct.

then the response that emerges is likely to be inappropriate. The emergence of an inappropriate response is far less likely to occur with a direct experience then with the vicarious (symbolic).

This situation is evident all too often in classrooms. A symptom of such a situation may appear when a student fails to understand an assignment, or an explanation of a problem, or cannot understand what he has read. Quite probably the symbols fail to evoke the proper attachments or associations. The direct experience is not so likely to involve this symbolic confusion. This is clear if one tries to use only words (verbal symbols) in describing the construction of a wheelbarrow. Any possible combination of symbols used in the description is likely to be confusing or inadequate.

It would seem therefore that responses to direct experiences (1) involve fewer areas of the brain (and hence are faster and more efficient), and (2) are less likely to cause associative confusion, than vicarious (symbolic) experiences.

2. *The Role of Perception*

Once the brain has received stimuli from the sense organs the many stimuli are reorganized into meaningful patterns. This process of reorganization is known as perception. To illustrate, the vast number of sensations and experiences that one receives at a ball game do not all influence the behavior of the spectator. Rather the brain assembles those sensations that are related to the game into a meaningful pattern. When the game is over many of the sensations previously disregarded now become focal points for a new and different pattern. Many of the sensations formerly of importance now slip into the background. The meaningful pattern thus varies with the game, and obviously with the spectator. For example, an ornithologist traveling through a forest would be attracted by a bird call, a botanist by the sight of a rare mushroom, a zoologist by the disappearance of the tail of a salamander under a log. Yet each would organize the vast number of stimuli that they received into something meaningful, in so far as he is concerned. As just stated, the meaningful pattern may vary with the person who receives the experience. Yet, some perceptual organization always takes place. This can be illustrated by the two diagrams (*A* and *B*) below.

A *B*

The stimuli of the separate dots of *A* organize themselves into a line, those of *B* into a square. If one were to say to himself, "They

do not look like a line (square), they are not a line (square), I refuse to see them as a line (square)" it would make little difference. Everyone would see the sequence of dots as a line and a square respectively. In other words it is impossible to stop the perceptual process.

This latter statement has many implications. If a student receives a direct experience it is probable that the important elements (stimuli) in that experience are present in their normal perspectives. Hence a correct perception is facilitated.

However, in a vicarious experience, all the elements meaningful to the correct perception may not be present, or if present, not in the proper perspective. However the perceptual process will take place despite these "flaws" and hence a false perception of the total situation may result.

Thus direct experiences are less likely to result in false perceptions than are vicarious.

This principle is clearly illustrated if one compares the viewing of a fight over television with the version given by a radio announcer. The vicarious radio experience can turn a mild tiff (as seen directly on TV) into a bloody debacle.

3. *The Role of Meaningfulness*

Obviously when an experience is presented meaningfully, it is learned and retained better than when the experience is presented without meaning. The following example will illustrate this point:

Suppose the following nonsense syllables are presented on flash cards to a group of students. Let us assume each card is exposed for one second.

OT
SORCSA
TAE
OSTA
WTO
SRHSOE
GAERL
DFLEI
HET
LEWDKA

If the subjects are then asked to reproduce the letter combinations they've seen, they generally can do about two or three satisfactorily.

Suppose then the experiment is repeated with the following list:

FIELD
EAT
TWO
OATS

THE
WALKED
LARGE
ACROSS
TO
HORSES

In this trial ordinarily six or seven can be reproduced successfully. Suppose it is again repeated with this list:

TWO
HORSES
WALKED
ACROSS
THE
LARGE
FIELD
TO
EAT
OATS

Invariably this list is produced correctly.

The experiment and implications are by this time clear. The same stimulus letters appeared in all three trials. In the first, both letters and words are scrambled; in the second, only words; in the last all are in proper context.

The point being made of course is somewhat similar to that made with respect to the perceptual process. A meaningful experience is one in which the elements of a situation are found in their normal relationships to one another. Direct experiences tend to be meaningful because the elements are present in their normal relationships to one another. Vicarious (symbolic) experiences tend to be less meaningful since it is impossible to present all the elements concurrently as they appear in the real situation. They are generally presented serially, in some cases out of order. Frequently related elements are not properly contiguous in time and space.

Hence, it may be summarized that direct experiences are superior to vicarious (symbolic) in that they (1) involve fewer activities of the brain mechanism, (2) tend to enhance the perceptual process, and (3) tend to be more meaningful.

The reason that prospective science teachers should be taught to use direct experiences is obvious. Laboratories and textbooks emphasize the vicarious (symbolic) experiences while certain other facilities emphasize the direct. This is especially true for those that involve field work and the use of community resources. If such be true then prospective teachers should be taught to use facilities outside the laboratory and textbook. What more need be said?

OBSERVATION OF A UNIT ON THE SUN*

SISTER MARY ALICE
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One dark dismal afternoon I walked into a third grade classroom as the teacher was asking her class if it had been a pleasant day. Some responded that it had been pleasant enough inside but not outside. Others were visibly affected by the weather. Discussion followed on where the sun was when it was not "out" and what were some of its other benefits besides providing cheerful days. From the discussion, many questions arose. Is the earth larger than the sun? Where did it come from? Which one really moves, the earth or sun? What makes the sun so hot and bright? Some of these questions were adequately answered but others were vague. How could they find the answers? Obviously, as these young potential scientists demonstrated that day, one of the primary virtues of the scientist is that of observation. He must be open-minded, orderly in procedure, deliberative, careful to use reliable sources, and curious. But the basis of all these habits is observance. Here is where we begin in our primary grades—making the child aware of the universe of which he is a part.

In the development of a curriculum undertaken at Saint Xavier College in Chicago, a curriculum study is being made which embraces an entire educational program from kindergarten to college. Science, of course, is given very special attention. At the primary level we begin with a study of the world about us. But this study must have a pattern and not merely one dependent upon seasonal change. A definite pattern, one developed early in education and gradually expanded in richness of detail, and the only one wide enough to synthesize all reality is found in Sacred Scripture. With so many well-written, beautifully illustrated, authoritively prepared materials on science today, there is very little that is not materialistic either in reference or in absence of proper emphasis. Using Sacred Scripture as a frame of reference, we constantly give science its rightful position. At the primary level, then this means beginning with the story of creation given in the first chapter of Genesis. This scriptural story is the basis for the inter-relation of social studies, religion, "science," or nature study, music and literature. Our emphasis is upon directing the totality of the child's experience toward an aesthetic appreciation of God's wisdom, power, and beauty manifested in His creation. The curriculum is structured so that all the child's learning will bring about a vivid realization

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* Read at the Elementary Science Section of the Central Association of Science and Mathematics Teachers at Detroit, November 25, 1955.

"both imaginatively and intellectually that the universe is an ordered whole which reflects the wisdom and power of God."[1]

Since the Sacred Scriptures is the core of the curriculum, its theme at the various levels penetrates into the nature study. At the third level of the elementary school where we shall observe our unit on the sun, the emphasis is on an appreciation of God's love, power, wisdom, beauty, and knowledge as reflected in His providential care for all His creatures. This is attained through a consideration of the interdependence of all living things, the maintenance of the balance in nature, and the dependence of all living things upon non-living creatures. In the social studies we see this same theme, the providence of God, reflected in the family, the provider of the basic needs of the individual. How much more unified and stable is such a curriculum which has as an integrative principle that progresses through the entire elementary school than one I heard of recently. Here a study of prairie dogs became the basis for the curriculum development. The activities of the prairie dog in his natural habitat indicated the direction of study.

What is the effect of a curriculum based upon Sacred Scripture? Primarily, it puts all knowledge into a pattern which gradually completes a single, unified picture. Isolated bits of knowledge not fitting into some definite and continued pattern will either be forgotten, remain isolated in the mind, or possibly be poorly or incorrectly placed or applied. And not only must the facts fit into a plan but they must be presented in such a way as to bring about an appreciation. This is fairly demanded by the imaginative, poetic nature of the young child who is naturally inquisitive about his "sighted but unexplored world."

The third graders I was visiting were already familiar with the story of creation so they knew that in the beginning God created "a greater light to rule the day and a lesser light to rule the night," and that these gifts were made for man's use to help him attain his destiny. But now the teacher began to work toward her specific objectives of this phase of study:

1. To develop an appreciation for God's providence
2. To develop habits of observation
3. To unify the knowledge by a correlation with the language arts, music, and creative arts
4. To acquire further knowledge, commensurate with this age level, that science has discovered through the years:

The sun is the source of heat and light,
It causes shadows,

[1] The Liberal Education of the Christian Person. A Progress Report prepared by the faculty of Saint Xavier College.

It helps plants and animals to grow,
It causes day and night by reason of the earth's movement in relation to it,
It effects seasonal change by reason of the earth's movement around it.

Some of the effects of the sun could be seen by experiment. Two plants were observed over a period of time; one thriving in the light of the sun, the other slowly fading in a dark corner. Some answers to questions had to be obtained from reliable sources having the proper instruments and more scientific knowledge. This directed reading and led to reports and discussion. One youngster even tackled the Encyclopaedia Britannica; others started family groups reading and retelling. But demonstrations accompanied reporting so the source of light was shown to cause day and night as an artificial light was played upon the slowly rotating globe. Placing a figure in the region of the Great Lakes and rotating the globe, first one way and then the other, the teacher asked the children to decide whether the globe turned in the same direction as the sweeping second hand of the room clock or in a counter-clockwise direction. Those who had relatives living on the west coast were able to contribute the fact that it is noon in Chicago before it is noon in California. This fact helped to decide that the movement was in a counter-clockwise direction.

The cause of the seasons was demonstrated as others reported reading about the movement of the earth around the sun. But what of the size of the sun? How could it be so much larger than the earth when they could see it looked so small? The teacher had the children hold their fingers before their faces and compare the size of objects at a distance with the size of the finger. Windows in buildings opposite looked smaller than their fingers because they were farther away. Distant trees were only half of the size of their fingers. In this way they observed that objects looked smaller the farther away they were. They began to comprehend how large the sun really is when it looks as big as it does and yet is so far away.

One sunny day observation was made of a shadow stick planted in a sunny spot. The direction and length of shadows were observed in the morning before school, at noon, and upon leaving in the late afternoon. This led to a lesson on directions and the period in history when sun dials were time keepers. Sun dials were made by making a pointing figure which was affixed to a nail in the center of a square block. At eight o'clock in the morning the place was marked where the figure's shadow pointed. Each hour until sunset the hour was marked. The directions, east, west, north, and south, were also

marked upon the square. The following days the children had great fun telling time with their sun dial.

"But how did people know directions at night?" someone asked. They heard and read about the North Star. Then, they observed it at night. They shared their observations by making a shadow box which pointed out the North Star and showed the movement of the Dippers around it. This was knowledge they gained by reading and they kept their shadow box to compare with the seasonal sky. It led naturally to their next study which was about the night sky.

During the creative art period, the children drew pictures showing the benefits of the sun; its effect upon the earth, and the people on the earth. Not only did the study stimulate reading but directed the subject of creative writing as well. The children wrote an imaginary story of what would happen if the sun stopped shining over a period of time. Even the music period was related to this theme as the children learned a plain chant for the Canticle of the Three Children which is taken from the Old Testament in which the children called upon all the creatures of the Lord to bless the Lord.

It would have been ideal to have been able to bring these children here today for you to hear them in a discussion period that followed this unit of study but since that was impossible, I have brought the next best thing, their voices. We taped the discussion toward the close of their work and perhaps you can judge for yourself how they profited by their study.

CHEMICAL INDUSTRY PLEDGES AID TO SCIENCE EDUCATION

The chemical industry urged increased emphasis on sound technical and scientific training, particularly in the secondary schools, as vital to the nation's future in a statement issued by the Manufacturing Chemists' Association, Inc.

Addressing some 2,000 delegates from every state to the White House Conference on Education, the MCA called technological progress essential to maintain America's plane of living and to prevent America from being outdistanced by other countries, with possibly disastrous results.

"Technological advances," said MCA, "confront the American people with the problem of adjusting themselves to a way of life different from the past and continuing to change at a rapid rate.

"Equally important, we must soundly educate an adequate number of men and women to help sustain and promote this new civilization.

"Industry is conscious," the MCA statement concluded, "that in the days ahead it must shoulder increased responsibility in the field of science education. The chemical industry, for one, pledges itself to meet those responsibilities, particularly on local levels where education has its roots."

Pocket Uranium Kit for both the amateur and professional prospector can be used to locate the radioactive mineral without a Geiger or scintillation counter. The kit contains sample ores, testing devices and instructions.

WORDS AS A BASIC FACTOR IN UNDERSTANDING ALGEBRA

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In algebra, as in all other fields, language is the basis for thought. Each idea which the algebra student must grasp is represented by a word, for example, *root*, *ratio*, *equation*, or *factor*. And mathematical reasoning proceeds from the premises contained in definitions of such words.

It is obvious, therefore, that high school students must have a complete understanding of words used in algebra to understand fully the important algebraic concepts.

Special effort is needed to give students this comprehansion. Admittedly, it is not an easy task. A series of brief, isolated definitions will not create the desired richness of understanding. Rather, entire concepts must be built for the words used in the algebra classroom.

The task can be simplified by grouping the words needed for a mature understanding of the subject into three categories:

1. The basic vocabulary of arithmetic.
2. Arithmetic words which take on additional meanings in algebra.
3. Words the student encounters for the first time in algebra.

Each of these groups of words poses special problems. Each requires special handling. And each provides the algebra teacher with opportunities for increasing student understanding and appreciation of the subject.

Let us discuss these three groups, one at a time.

1. The first of the three categories is the basic vocabulary of arithmetic. A beginning algebra student may have forgotten or may never have learned some of the language of arithmetic. Just as the *skills* of arithmetic are necessary in algebra, so are the *words* of arithmetic.

As teachers, we might profitably ask ourselves: "Do our students really know the arithmetic words we expect them to know? When we 'explain' something by talking about dimensions, perimeters, products or averages, is the fog clearing or becoming thicker?"

An important—and logical—first step is to test students for deficiencies in understanding arithmetic language. Mathematical vocabulary tests can be important aids. They can also be effective devices for demonstrating to pupils the importance of mastering new words in learning algebra.

The tests undoubtedly will reveal a number of arithmetic words

that need considerable reteaching. Enlivening review and reteaching and making the work challenging are essential to offset student attitudes of "This is old stuff," and "I already know that—I don't need to study it."

When considerable ground has been covered, methods that add the stimulating elements of chance and challenge often work well. For example, a set of cards, each card bearing an important word for review, may be placed on the teacher's desk with the blank side of the cards turned up. Students may be called on, one at a time, to choose a card from the set and to define and demonstrate (where feasible) the meaning of the word on the card chosen.

Another effective review technique is the "guess what" game, in which the teacher defines a word or demonstrates a process and asks the students to tell the word or name the process. For example, the teacher may say, "If I multiply 3, 5, and 2 and obtain 30, what name do I give to the answer I found by multiplying?" The teacher may also write an equation such as $3 \times 5 \times 2 = 30$ on the board and have the students identify or define factors and product.

A good method of capturing the interest of students in a review of arithmetic words is the use of cross-number puzzles. These provide review not only of arithmetic vocabulary but also of arithmetic skills. Perhaps the best way to use such puzzles is to employ a set of them in which each puzzle is designed to concentrate on one particular phase of arithmetic.

For example, one cross-number puzzle might deal entirely with division, reviewing all the words which apply to division. Typical definitions in such a puzzle might be "Quotient when 4 divides 116," "Remainder when 209 is divided by 18," and "Dividend when the divisor is 7 and the quotient is 32." To solve the puzzle, a student must not only be able to define but must also be able to use all the terms involved. Some students may not only like to solve cross-number puzzles, but to devise them as well.

Regular follow-up reviews of arithmetic words are important as algebra work proceeds, because many of the arithmetic words enter into the discussions and the procedures of algebra. The beginning of each new chapter or unit is an excellent point for the review of arithmetic words which will be involved in the work of the chapter or unit.

2. The second of the three important vocabulary areas in algebra involves familiar arithmetic words for which the student must learn additional meanings. One of the biggest challenges for the beginner in algebra is the necessity for enlarging his understanding and proceeding from the familiar, but limited, concepts of arithmetic to the more general concepts of algebra.

For example, the student is sure he knows the meaning of *adding*. But in algebra he finds that he must think of adding as *combining* and that the results of adding (combining) signed numbers can be greatly different from what he might expect as a result of his experience with addition in arithmetic.

Vocabulary development plays a particularly important role in developing the broader concepts required for algebra. Take the word *number*, for example. In arithmetic, this word usually has a rather simple and restricted meaning for the student. Upon hearing the word *number*, he may think of a symbol such as 1, 4, or 9, or a corresponding group of things.

But in algebra the student must have a generalized definition for this word. *Number* for the algebra student should be a concept that includes the meaning of cardinal numbers, as 1, 4, or 9; literal numbers, as c or x; irrational numbers; and transcendental numbers. The student should be helped to form a generalization from experiences with specific "number situations."

In order to learn new meanings for familiar words, the algebra student must read carefully. He must be able to comprehend written explanations and instructions. The student may, of course, read glibly every word in his algebra book. But if the words have the same meaning for him as they did in sixth-grade arithmetic, he inevitably will encounter difficulty in the study of algebra. This is perhaps the most important reason for giving as much attention to teaching new meanings for familiar words as is given to teaching completely new words.

3. The third of the three categories consists of the mathematical terms which the student encounters for the first time in the algebra classroom. This group includes words which contain basic ideas or elements of algebra, such as *coefficient* and *abscissa*.

Some words which are new to the student in algebra class are not necessarily unfamiliar to him, because they have non-mathematical meanings. The teacher, in introducing words such as *root*, *negative* and *constant*, may find it desirable to relate their common meanings to their special algebraic meaning, in order to clarify the latter.

Sometimes a good starting point for an explanation of a new word is an object, a picture, a diagram, or some other type of visual aid. Thus, in explaining signed numbers, the use of a thermometer is very good.

Many teachers favor having students write definitions of new words in special sections of their notebooks, in order to focus attention on the words and to simplify review by the student. Sometimes students find that diagramming an explanation of a problem as they read it helps to clarify the meaning of the words involved.

While the word-teaching methods which teachers employ vary widely, the ultimate objective remains constant—to facilitate the teaching of algebra. Obviously, students who really understand the terms learn faster than do students who constantly must struggle with the unfamiliar. An acute awareness of the importance of vocabulary and a willingness to take special pains to broaden students' understanding of algebraic terminology can be important elements in making the subject more meaningful.

HOW CAN A JUNIOR HIGH SCHOOL MATHEMATICS TEACHER STRENGTHEN THE SCIENCE COURSE?*

Alfred Capoferi
Tappan Junior High School, Detroit 4, Mich.

The main purpose of this convention or any convention is to share in the exchange of ideas. It is the expressed hope of this speaker that you appreciate the exchange of ideas after you leave this room.

The main topic of this discussion will be methods and suggestions that will enable mathematics teachers to strengthen the science course. However, before I get into the techniques employed by myself and two teachers at Tappan Junior High School, you should first be properly oriented to the school situation in which these methods are employed.

Tappan Junior High is located on the west side of Detroit on the corner of American and Webb avenues. It houses a population of approximately 1500 students and has a faculty of sixty-five teachers and administrators. Of these sixty-five faculty members, ten are members of the exact-science department. The exact-science department consists of six mathematics and four science teachers. The science teachers teach in rooms that were specifically designed for science and there is a sufficient supply of physical and chemical equipment with which to successfully carry on a functional teaching program.

Moreover, the students of Tappan Junior High School are homogeneously classified according to mental ability. Be it sufficient to say here that a very elaborate selection process is used to classify pupils so they are grouped with peers with similar mental potential. This process of homogeneous grouping permits a high degree of subject matter correlation between the science and the mathematics teachers. Furthermore this close cooperation between the science

* Read at the Junior High School group program of the Central Association of Science and Mathematics, Teachers, Detroit, November 26, 1955.

and the mathematics teachers is enhanced by the proximity of the science and mathematics classrooms.

As you perhaps have already surmised, the teaching conditions at Tappan Junior High School are most conducive to subject matter correlation type of teaching. However, the correlation of the science and mathematics courses is beneficial to the teachers and pupils alike, only if the educational philosophy of the involved teachers is alike. They must believe that we cannot draw a line between science and mathematics and call them separate entities within themselves. They must believe that mathematics and science are inter-related and that each teacher will draw concrete and functional life experiences from the other's subject matter field that will make his subject matter concepts more meaningful to his pupils. For example, the mathematics teacher should use practical applications from science, whenever possible, to demonstrate and give meaning to a mathematical concept. On the other hand, the science teacher should utilize mathematics concepts and generalizations taught in the "math" class to make his scientific principles more meaningful to his pupils. Two teachers can correlate the teaching of mathematics and science quite successfully if they emphasize the inter-dependence of mathematics and science to their pupils by example. Each teacher must draw upon the others' subject matter field to give variety, vitality, vividness and meaning to the principles and concepts he is trying to teach. If this process is followed, a mathematics teacher makes science more realistic by doing so.

On September 7, 1954, Mr. Hackett, Mr. Honkanen and myself, started our teaching experience at the Tappan Junior High School. As we worked together and became better acquainted, we realized that our basic educational philosophy was somewhat similar. It paralleled the philosophy of teaching science and mathematics as I have described it. We discussed various ways of teaching science and mathematics more effectively. I was a new department head at Tappan, and I did not want to try out any new ideas quite so soon; but the opportunity soon presented itself last June in a form of an invitation to participate in this program. My colleagues and I decided that this term was a good time to start our new approach or emphasis on science in the teaching of mathematics. The three of us decided that we could correlate the teaching of science and mathematics and make it more effective than teaching mathematics and science by more conventional methods. So this semester our teaching program was very well suited to correlation of the teaching of mathematics and science. The teaching program was arranged so Mr. Hackett taught mathematics to one 9B group the 6th hour and Mr. Honkanen taught the same group science the 3rd hour; while Mr.

Honkanen taught another 9B group mathematics the 2nd hour and Mr. Hackett taught this group science the 5th hour. Moreover, these two gentlemen teach in rooms right next to each other so they can carry on a daily evaluation of their presentations and progress.

Once we decided upon what classes were involved in our experiment, we began to examine the subject matter areas of both the mathematics and the science courses of study to determine the areas in which various mathematics concepts could have more meaning if they were illustrated with science applications. The result of our efforts is a functional list of arithmetic concepts that have scientific application in the mathematics class-room. We believe that this approach strengthens the science course as well as making the mathematics class more interesting.

The following arithmetic generalizations have a science application:

MATHEMATICS CONCEPTS	*SCIENCE APPLICATION*
(1) Ratio and proportion	Simple levers, Archimedes principle
(2) Metric system	Weights—measurements
(3) Balancing of equations	Balancing chemical equations, density, photosynthesis
(4) Volumes and their formulas	Volumes of aquaria
(5) Averages	Temperatures—horsepower
(6) Positive and negative numbers	Temperature (boiling point—freezing point)
(7) Graphs—bar, line, circle	Composition of air—temperature
(8) Ordinary computation—whole numbers, fraction and decimals	Science problem solving in all areas
(9) Per cents	Solutions—compounds
(10) Application of various units of measure	Metric system
(11) Use of ruler, compass, protractor	Measuring
(12) Geometry	Structure of matter
(13) Applications of algebraic symbolism	Horsepower—temperature formulas
(14) Use of tables	Density, melting—freezing tables

This list represents some of the many mathematics concepts that have scientific application and can be a major contributing factor in strengthening the science course. These scientific illustrations of mathematics principles give functional values to the pupil's understanding of mathematics, as well as making him cognizant of the inter-dependence of mathematics and science.

Therefore, any zealous teacher of mathematics can strengthen a science course by—

(1) relating science to the teaching of mathematics by concrete examples,

(2) emphasizing the dependence of science on mathematics for its expression and statistical interpretations, and

(3) correlating the teaching of important mathematics concepts

with their direct application to scientific principles in the science class-room.

This mathematics-science approach to the teaching of mathematics is needed more today than ever before. The demand for trained scientists in an atomic era is so great at the present time that it borders the critical stage. As international tensions mount, our technological leadership and superiority is in jeopardy. Technological and scientific leadership has been a symbolic characteristic of the rise of our country as a world power. If this technological advantage is to be maintained, the junior high school teachers must seek out, identify, and encourage those students who have the innate capacity for advanced scientific training; the junior high school mathematics teachers must kindle the interest, fire the imagination, and inspire these young people to continue into high school and college for advanced scientific training. This is our particular task; it can be accomplished by conscientious mathematics and science teachers through cooperative planning.

MORE TEACHERS NEEDED

If America's predicted living standard is to raise 50% by 1956, we must have an expansion in the number of people entering the teaching profession, dynamic salesmanship and stimulation in the field of creative engineering.

These three points were stressed by Joseph A. Anderson, general manager of AC Spark Plug Division of General Motors, in an address before the University of Minnesota Institute of Technology Alumni Association. Anderson was the principal speaker at the Association's 17th annual dinner meeting.

"The teaching profession is the basis of our economy," said Anderson, "because it determines the capabilities of our young people. Presently our need for teachers is most critical in the science and engineering areas."

Related to selling the AC general manager had this to say, "The importance of selling as a stimulant to improved living is obvious. Our economy depends on getting people to use their purchasing power. We need to enourage more young people to consider sales as a career."

America's rise in living standard rests heavily on the shoulders of the creative engineer, Anderson told his audience. "We need engineers to conceive in a greater degree the devices of tomorrow that will obsolete the devices of today and will also add to the devices that will be desirable to own. In way of explanation, he pointed out that AC had created some 18 basic components needed on an automobile since he joined the firm in 1924. At that time AC produced only spark plugs and speedometers.

Electronics kit simplifies the teaching of electron tube theory, radio transmitting and receiving and basic radar and television. Containing 108 component parts, a 400 page work book and 73 related experiments, the kit is a do-it-yourself teacher.

THE USE OF PROJECTS IN THE TEACHING OF PHYSICS*

GLENN BRAY
Grosse Pointe High School, Grosse Pointe, Mich.

Technical advances made in research and in industry during the Second World War and in the years that followed have created a demand for more young science-trained people than the high schools, colleges, and universities have been able to supply. The demand for engineers and laboratory technicians is increasing year after year faster than the number of college graduates qualified to meet it. Haven't you as science teachers wondered what you could do to encourage more capable young people to make science and engineering their life's work?

I believe that one method of arousing the interest of more students in science; of motivating them to do better work when they are enrolled in your classes; of finding out early in the course whether they can apply the principles you are teaching; of encouraging them to use the library more in preparing their lessons; of encouraging them to do some original research; of discovering and encouraging them to use natural mechanical ability is by the use of projects in the teaching of science.

After years of trial, I am so convinced of the educational merits of projects that I now require each of my physics students to present a project of his own choosing each term as part of his work. I count the project mark as from one-third to one-half the last marking period grade.

Early in the first semester of each year I choose some of my better projects from past years and have some of the students arrange them as an exhibit in the display cabinets in our halls. The large number of students gathering around the displays, and the fact that many 9th, 10th, 11th, and 12th-grade students go to their counselors and come to me inquiring about physics shows that it is an excellent method of arousing interest in science and encouraging them to enroll in science classes. At the beginning of each semester I also make a carefully selected display of many of my better projects of previous terms on the bulletin boards and the adjoining counter space in my laboratory. The students are encouraged to examine the exhibits carefully for a day or two. We then devote a period or two to discuss the purpose of projects and to answer the many questions of the students concerning the principles involved and as to whether

* Read at the Physics Section of the Central Association of Science and Mathematics Teachers, Detroit November 25, 1955.

they can work on an improvement of the same project or a similar one. Some projects are worked on by two or three students in succeeding terms and it is surprising how much some students can improve upon the work of someone else once he has understood the principle involved and has adopted it for his own.

I lead them to see that the projects displayed can be grouped under four categories:

1. Biographical sketches of scientists and their contributions to physics. Forty different scientists have been chosen as the accompanying list will show.
2. Description of industrial equipment and processes that involve physical principles. (27 papers)
3. Accurate machine drawings of machines mentioned in their text or used in industry that illustrate some law or principle of physics. (30 drawings)
4. Either cut-away models or actual working models of machines and equipment that will help to make the application of physics more understandable and interesting. (48 models)

It is decided during the discussion that probably from 1000 to 2000 words will be needed to cover adequately a subject in categories 1 or 2. It is brought out that a bibliography should be included giving the sources of material used.

Students who choose categories 2, 3, and 4, are urged to make an outline of what they plan to do and then come to me to discuss their plans before they start the actual drawing or model. This gives the teacher a chance to discuss with the student the practicability, importance, and desirability of their ideas. This also offers the teacher the opportunity to point out difficult and dangerous procedures, and by questions and suggestions to get the student to see all the applications involved and the most practical way of making these evident to others who may later see or use their drawings or models. I have found that when a student comes to me to discuss his project that there is an entirely different feeling and relationship from what there is in a regular classroom situation. He is usually enthusiastic, talks freely, and usually has a good grasp of what he plans to do. Since he probably has chosen the one thing he likes best in the semester's work, he has confidence in himself; and since he usually wants to do a superior piece of work, he is thirsty for information, sources of material, and guidance. These conferences are truly enjoyable to both the student and the teacher.

Some of the projects make excellent and effective demonstration equipment that would be expensive or impossible to purchase.

There is no doubt in my mind that the average student has a much better understanding of an internal combustion two-cycle engine when I use a cut-away model of an actual $\frac{3}{4}$-horsepower engine in which the piston is painted red, the connecting rod blue, the

crankshaft yellow, the intake port white, and the exhaust port green, than when I use a picture in our textbook.

The electronic Tesla coil which was constructed by a student who has graduated, and which will be demonstrated by one of my present students, never fails to arouse interest in electronics, vacuum tubes, condensers, induction coils, etc. when it lights a fluorescent light held in the hands of a class member at a distance of several feet. The VandeGraff generator and transverse-wave and standing-wave projects which will be demonstrated by students also, never fail to arouse interest in atomic structure and wave formations.

Unless the project has involved the outlay of a large sum of money in its construction, the students are expected to leave it at the laboratory so that it can be used as demonstration equipment to motivate other students. Many students who have made radio transmitters, receivers, Hi Fi phonographs, stroboscopes, and other expensive equipment, have been allowed to take them home after demonstrating them to each of my physics classes.

Students who choose to write biographical sketches of a scientist and his work, or to describe an industrial process, are encouraged to give an oral report before their classes. This serves the dual purpose of imparting the knowledge they have gained to their classmates and, what is perhaps more important, it gives the student the feeling of self-satisfaction and pride that comes from posing as an authority before his friends and presenting a piece of work that is well done.

I have found that many students have consistently done better work in physics after they have received the praise of their fellow-students and their teacher for having presented an excellent project and explained its applications. One soon discovers that it is not always the student that can write the best tests who can construct the best projects. Sometimes very good students do not seem to be able to apply their knowledge in a practical way. Others do not appear capable of overcoming the structural and mechanical difficulties involved and thus present mediocre projects. Sometimes average students present projects that would put equipment purchased at equipment houses to shame.

I get great satisfaction when I find a superior student who can apply his knowledge and produce an excellent project that displays his knowledge and craftsmanship. It is a pleasure to recommend such a student to some engineering college.

A teacher will soon discover that the use of the project method of teaching does not lighten his teaching load—it rather increases it—but the results obtained in motivating the students and the mastery they achieve in the subject matter and the success they later achieve in college are ample reward for the additional effort involved.

they can work on an improvement of the same project or a similar one. Some projects are worked on by two or three students in succeeding terms and it is surprising how much some students can improve upon the work of someone else once he has understood the principle involved and has adopted it for his own.

I lead them to see that the projects displayed can be grouped under four categories:

1. Biographical sketches of scientists and their contributions to physics. Forty different scientists have been chosen as the accompanying list will show.
2. Description of industrial equipment and processes that involve physical principles. (27 papers)
3. Accurate machine drawings of machines mentioned in their text or used in industry that illustrate some law or principle of physics. (30 drawings)
4. Either cut-away models or actual working models of machines and equipment that will help to make the application of physics more understandable and interesting. (48 models)

It is decided during the discussion that probably from 1000 to 2000 words will be needed to cover adequately a subject in categories 1 or 2. It is brought out that a bibliography should be included giving the sources of material used.

Students who choose categories 2, 3, and 4, are urged to make an outline of what they plan to do and then come to me to discuss their plans before they start the actual drawing or model. This gives the teacher a chance to discuss with the student the practicability, importance, and desirability of their ideas. This also offers the teacher the opportunity to point out difficult and dangerous procedures, and by questions and suggestions to get the student to see all the applications involved and the most practical way of making these evident to others who may later see or use their drawings or models. I have found that when a student comes to me to discuss his project that there is an entirely different feeling and relationship from what there is in a regular classroom situation. He is usually enthusiastic, talks freely, and usually has a good grasp of what he plans to do. Since he probably has chosen the one thing he likes best in the semester's work, he has confidence in himself; and since he usually wants to do a superior piece of work, he is thirsty for information, sources of material, and guidance. These conferences are truly enjoyable to both the student and the teacher.

Some of the projects make excellent and effective demonstration equipment that would be expensive or impossible to purchase.

There is no doubt in my mind that the average student has a much better understanding of an internal combustion two-cycle engine when I use a cut-away model of an actual $\frac{3}{4}$-horsepower engine in which the piston is painted red, the connecting rod blue, the

crankshaft yellow, the intake port white, and the exhaust port green, than when I use a picture in our textbook.

The electronic Tesla coil which was constructed by a student who has graduated, and which will be demonstrated by one of my present students, never fails to arouse interest in electronics, vacuum tubes, condensers, induction coils, etc. when it lights a fluorescent light held in the hands of a class member at a distance of several feet. The VandeGraff generator and transverse-wave and standing-wave projects which will be demonstrated by students also, never fail to arouse interest in atomic structure and wave formations.

Unless the project has involved the outlay of a large sum of money in its construction, the students are expected to leave it at the laboratory so that it can be used as demonstration equipment to motivate other students. Many students who have made radio transmitters, receivers, Hi Fi phonographs, stroboscopes, and other expensive equipment, have been allowed to take them home after demonstrating them to each of my physics classes.

Students who choose to write biographical sketches of a scientist and his work, or to describe an industrial process, are encouraged to give an oral report before their classes. This serves the dual purpose of imparting the knowledge they have gained to their classmates and, what is perhaps more important, it gives the student the feeling of self-satisfaction and pride that comes from posing as an authority before his friends and presenting a piece of work that is well done.

I have found that many students have consistently done better work in physics after they have received the praise of their fellow-students and their teacher for having presented an excellent project and explained its applications. One soon discovers that it is not always the student that can write the best tests who can construct the best projects. Sometimes very good students do not seem to be able to apply their knowledge in a practical way. Others do not appear capable of overcoming the structural and mechanical difficulties involved and thus present mediocre projects. Sometimes average students present projects that would put equipment purchased at equipment houses to shame.

I get great satisfaction when I find a superior student who can apply his knowledge and produce an excellent project that displays his knowledge and craftsmanship. It is a pleasure to recommend such a student to some engineering college.

A teacher will soon discover that the use of the project method of teaching does not lighten his teaching load—it rather increases it—but the results obtained in motivating the students and the mastery they achieve in the subject matter and the success they later achieve in college are ample reward for the additional effort involved.

THE GROWING EMPHASIS ON SCIENCE AND MATHEMATICS IN INDUSTRY*

ANDREW LUFF
Western Michigan College, Kalamazoo, Mich.

Before we begin to discuss the emphasis on science and mathematics in industry today, it seems important to take a quick look at the historical significance of industry and to develop something of a relative understanding of why many of the problems now faced by modern industry are still unsolved. We speak quite freely of the history of industry or of a particular organization or about the history of our industrial economy of labor or of the peaks and valleys of economic conditions. Actually, it is important that we consider what we are talking about when we say, "History." What is history as far as industry is concerned?

Let us assume that the beginning of history is the beginning of man in his present form and establish two points, one for the beginning (X) and one for now—today (X'), and let us plot some points, along the line between them in this manner:

$$X \qquad\qquad\qquad\qquad 1 \qquad\quad 2 \quad 3 \quad 4X'$$

At point No. 1, a very significant historical event occurred. Man discovered *fire!* That was a big discovery. He didn't know what it was or what caused it, but he observed it for the first time.

During all of the period preceding this event, he had been oblivious to this natural phenomenon the sources of which all of us carry in our pockets today. How he became conscious of fire, we do not know. It might have come about by lightning striking a tree; perhaps a volcanic eruption started a bush fire. Be that as it may, he did become conscious of it, thus opening the unlimited vistas for further development. But even with this key to future possibilities, his progress was slow.

Moving along to point No. 2, another significant development took place on our historical chart. Man discovered that by planting a seed or a sprig, he could raise crops to feed himself, and that by domesticating animals, he could make them work for him or eat them, whichever he chose. Up to then, he had lived on berries or on other vegetation or meat as he found it. But now, he could put a seed in the ground and something came up! Because of this discovery, he could stay in one place and depend upon his ability to grow his

* Read at the Junior College group program of the Central Association of Science and Mathematics Teachers, Detroit, November 26, 1955.

own food stuffs—rather than seek it out wherever it grew wild, consume it and move on. He forsook his nomad ways and became a communal being, staying in one place with his family and with other families.

Hundreds of years passed before he had evolved to point No. 3. Here the Egyptians built their pyramids, ancient civilizations began to flourish. In point of time on the line from the beginning to NOW, ancient history is almost yesterday.

Point No. 4, crowding "today," represents current history, the beginnings of English and German history, Shakespeare and Galileo. There is not room on the span of time to place a point indicating the American Revolutionary War or the much later beginning of the Industrial Revolution. And here we are! The history of the industrial age is too short to measure. There really isn't any history of industry.

For the purpose of more clearly illustrating the point, let us draw from another graph condensing the span of 500,000 years of history into a 50 year period.

X ______________ X'

50 years

For the first $49\frac{1}{2}$ years on this graph, man was without his own source of food. It took him that long to learn how to plant grain and raise it and to domesticate animals. On this graph, if we go back only two weeks, we go back through the Renaissance.

Industrial history began fifteen or twenty minutes ago. Thirty minutes ago Watt discovered the steam engine. We must consider these things to get our perspective. When we refer to the history of industrial enterprise, we are talking about something extremely young. We don't have any bench marks. Its all current. Industrial History is NOW!

We usually associate the beginning of the industrial revolution with the invention of the steam engine by James Watt about 1800. The first real use of the steam engine was in the Civil War in the early 1860's. It's just a little over a hundred years ago that the whole thing started. Industry began then, but not in the form we know it today. In 1953, Ford celebrated its 50th anniversary. In 1903, Henry Ford made his first auto. Roughly 50 years ago people saw their first auto; this, within the life span of some of us, certainly within the life span of our parents. How long have we had electric lights? Last year was the 75th anniversary of the invention of the first electric light bulb. All of these things we accept as so common place today had their beginnings within the memory of ourselves, our parents or grandparents. A hundred years ago the steam engine and

a horse had a race—and the horse won. It's only in the last few years that we have made the tremendous strides which have brought us to NOW.

The reason for developing this rather sketchy historical outline has been to point up the fact that the growth of industry and, coupled with it, the demands made of those who man it, has been truly revolutionary in nature. The amount of knowledge which is available for application in industry today staggers the imagination. Is it any wonder that the entire industrial population of this country is desperately attempting to obtain more people trained in the basic principles of mathematics and science? Industry has, in the short span of 100 years, passed through the age of horse power; steam power; electric power; gasoline power; diesel power; and is currently engaged in the age of atomic power. With each of these power sources, came new and challenging problems never before recognized.

The demand for the person trained in science and mathematics is increasing daily. Last Monday, November 21, Chairman Lewis L. Strauss of the Atomic Energy Commission warned of possible disaster because "Russia is winning the cold war of the classroom." He pointed out that between 1950 and 1960, which may be the most critical decade of our national existence, Russia is expected to produce 1,200,000 trained engineers and scientists against our 900,000. He said the United States requires from 45,000 to 50,000 new trained engineers every year and is getting half that number. When we realize that various studies indicate that industry needs from two to five technicians for every engineer, we begin to visualize something of the tremendous need in American industry for people with a science and mathematical background. From Mr. Strauss' remarks, we may conclude that the United States requires from 100,000 to 250,000 new technicians each year to back up our engineering team. This year, according to Mr. Henry H. Armsby, Chief for Engineering Education, Office of Health, Education, and Welfare, technical institutes, including Junior colleges, that offer technical-terminal training are expected to graduate about 13,500 trained technicians. Although this represents an increase of 25% over last year, the supply is far short of the demand.

And so it goes. More technical advancements, a far greater economy, a tremendous demand for trained people. The evidences of a growing emphasis on science and mathematics in industry are everywhere. And the problem is only beginning to be seen. The future is even more fantastic. Some excerpts from the Joint (Congressional) Committee on the Economic Report:

The value of all goods and services for 1955 is estimated to be $392 billion.

The total national output in 1965 should reach $535 billion, an increase of 50% from present rates.

The total number of people gainfully employed in the United States in 1955 is approximately 63,000,000.

In 1965, the Joint Committee says 76,000,000 people will be at work again representing an increase of some 50%.

In 1965, the 35 hour work week will be firmly established. Many industries will work only 30 hours a week.

In 1965, vacations will increase from two weeks to four weeks a year for nearly all workers.

In 1965 output per man-hour on the farm will be 2% higher than it is now; in the factory and in the office, output per man-hour will be about 3% higher.

These bare statistics suggest that educated minds and trained hands will be in ever greater demand for an ever increasing number of new kinds of jobs and occupations.

We have mentioned briefly the engineer and the technician. The demand for these people is tremendous and will continue to grow to presently unthought of proportions. But how about the average worker in industry? How is be heing affected by all this sudden emphasis upon science and mathematics in industry?

A subcommittee, headed by Representative Wright Patman has been taking testimony from the nation's top industrial and labor leaders on what automation may mean for employment, unemployment, productivity, and investment. Among those who gave their views was Walter Reuther, CIO president. Mr. Reuther put his finger on what seems to be one of education's most pressing problems as he commented, "If automation destroys unskilled jobs and creates skilled jobs, means must be found to train large numbers of of unskilled workers in the needed skills."

Mr. Reuther is also concerned about the worker who already has a highly specialized skill, but who finds his skill has been made valueless because a machine has taken over his job.

"If automation is going to displace workers in either of these two ways," Mr. Reuther went on, "we shall need a carefully organized retraining program to give them the skills they need."

The need for this type of training is being felt everywhere. The increased enrollments in adult education programs at the high school and college level is only one indication of the growing need. The programs of adult education in the junior colleges all over the country have grown immensely in the past few years. Programs of education carried on in industry have grown until today, it is rare to find a company which is not actively engaged in, or encouraging its employees to participate in, educational programs of all types.

A look at some of the courses now being offered and being well attended gives an insight into the degree of emphasis on science and mathematics in industry. Among the most popular adult education courses are Industrial Electronics, Applied Mathematics, Machine Tool Technology, Statistical Quality Control, and Industrial Uses of Atomic Power, to name only a few.

And who are attending these adult evening school courses? Engineers, technicians, and hourly paid workers; all caught in the tremendous surge toward the growing emphasis on science and mathematics in industry. We as educators must be ready! The schools are being pushed to the front in this struggle for survival. Hundreds of engineers and technicians must be readied and hundreds of thousands of workers must be retrained. The problem is gigantic. But if we remember that this all started between fifty and one hundred years ago, we won't waste our time looking for historical answers, but will face the problem with new vision and new foresight. We must look for ways to make science and mathematics the everyday language of the man on the street. We must find ways to make science and mathematics courses the most sought after courses in school, because science and mathematics have become the key to the future of our industrial civilization.

PROBLEM DEPARTMENT

CONDUCTED BY MARGARET F. WILLERDING
Harris Teachers College, St. Louis, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, Harris Teachers College, St. Louis, Mo.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solution should observe the following instructions.

1. Solutions should be in double spaced typed form.

2. Drawings in India Ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known reference to it.

4. Each solution or problem for solution should be on a separate page.

In general, when several solutions are correct, the ones submitted in the best form will be used.

LATE SOLUTIONS

2479, 2482, 2484. *Alan Wayne, Baldwin, N. Y.*

2485. *Proposed by Dwight L. Foster, Florida A & M College.*

A man started for a walk when the hands of his watch were coincident between three and four o'clock. When he finished, the hands were again coincident between five and six o'clock. What was the time when he started, and how long did he walk?

Solution by Richard H. Bates, Milford, N. Y.

Since the minute hand moves 60 minutes around a clock while the hour hand moves 5 minute spaces, the minute hand moves one space while the hour hand moves 1/12 of a space.

Let x equal the number of minutes past 3 when the hands will be coincident. Then while the minute hand moves these x minutes the hour hand will move $(1/12)x$ spaces. But the minute hand, at 3 o'clock, lags the hour hand by 15 minute spaces. Hence:

$$(1/12)x = x - 15$$

$$x = 12x - 180$$

$x = 16$ and $4/11$ minutes past three.

Similarly, the hands of the clock will be coincident at 27 and 3/11 minutes past 5 o'clock. Thus, the man started at 16 and 4/11 minutes past 3 and walked for 2 hours and 10 and 10/11 minutes.

Solutions were also offered by Leon Bankoff, Los Angeles, Calif.; Charles H. Butler, Kalamazoo, Mich.; Joe Kennedy, Madison, Wis.; A. MacNeish, Chicago, Ill.; J. Byers King, Denton, Md.; J. W. Lindsey, Amarillo, Tex.; J. H. Means, Austin, Tex.; Alan Wayne, Baldwin, N. Y.; and the proposer.

2486. *Proposed by Christos B. Clavas, New York, N. Y.*

Take the parabola $y^2 = x$. Join the origin, O, with any point, P, on the parabola. From P draw a perpendicular to OP intersecting the x-axis at the point G.

Prove that $OG = 1/\sin^2\theta$ where θ is the angle XOP.

Solution by Leon Bankoff, Los Angeles, Calif.

Let (x, y) be the co-ordinates of P.

By similar triangles,

$$OG/OP = OP/x = OP/y^2$$

Hence

$$OG = OP^2/y^2 = 1/\sin^2\theta$$

Solutions were also offered by Richard H. Bates, Milford, N. Y.; Joe Kennedy, Madison, Wis.; F. A. Lee, Williamsburg, Va.; A. MacNeish, Chicago, Ill.; J. H Means, Austin, Texas; and Alan Wayne, Baldwin, N. Y.

2487. *Proposed by A. R. Haynes, Tacoma, Wash.*

Solve:

$$(x+a)^4 + (x+b)^4 = 17(a-b)^4$$

$$(x+a) - (x+b) = (a-b)$$

Solution by Richard H. Bates, Milford, N. Y.

Since the second equation is an identity, it can be neglected and the following substitutions made in the first equation:

Let: $x+a=y$ from which $x=y-a$; and $(a-b)=z$

$$y^4+[y-(a-b)]^4=17z^4$$
$$y^4+(y-z)^4=17z^4$$

Expanding:

$$y^4+y^4-4y^3z+6y^2z^2-4yz^3+z^4=17z^4.$$

Collecting terms:

$$2y^4-4y^3z+6y^2z^2-4yz^3-16z^4=0.$$

Dividing both sides by 2 and factoring:

$$(y+z)(y-2z)(y^2-yz+4z^2)=0$$

from which:

$$y=-z;\ 2z;\ \frac{z(1+\sqrt{-15})}{2};\ \frac{z(1-\sqrt{-15})}{2}.$$

Replacing for y and z:

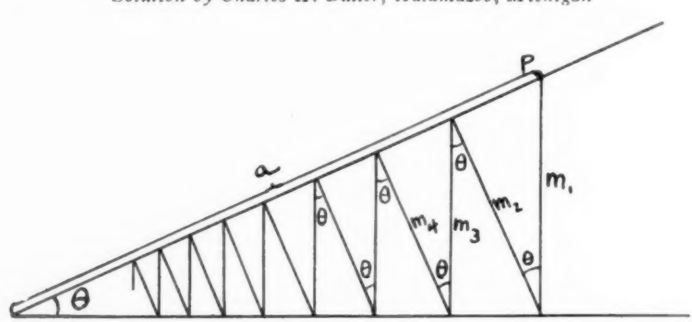
$$x=b-2a$$
$$x=a-2b$$
$$x=-a+(a-b)\frac{(1+\sqrt{-15})}{2}$$
$$x=-a+(a-b)\frac{(1-\sqrt{-15})}{2}$$

Solutions were also offered by Charles R. Berndstan, Vinalhaven Me.; J Byers King, Denton, Md.; Alan Wayne, Baldwin, N. Y.; and the proposer.

2488. *Proposed by C. W. Trigg, Los Angeles City College*

On one side of an angle $\theta<90°$ there is a point, P, at a distance a from the vertex of the angle. From P a perpendicular is dropped to the other side of the angle; from the foot of this perpendicular another perpendicular is dropped to the first side. This process is continued indefinitely. Show that the length of the broken line is $2a \csc\theta \cos^2\theta$. Also show that when $\theta=\pi/4$ the length of the broken line is equal to the perimeter of the triangle formed by the first perpendicular and the sides of the angle.

Solution by Charles H. Butler, Kalamazoo, Michigan



PART 1

Referring to the accompanying diagram, note that

$$m_1 = a \sin\theta = a \sin\theta(1)$$
$$m_2 = m_1 \cos\theta = a \sin\theta(\cos\theta)$$
$$m_3 = m_2 \cos\theta = a \sin\theta(\cos^2\theta)$$
$$m_4 = m_3 \cos\theta = a \sin\theta(\cos^3\theta)$$
$$\cdots\cdots\cdots\cdots\cdots\cdots$$
$$m_n = m_{n-1} \cos\theta = a \sin\theta(\cos^{n-1}\theta)$$
$$\cdots\cdots\cdots\cdots\cdots\cdots$$

Since this process continues indefinitely we have

$$\sum_{i=1}^{\infty} m_i = a \sin\theta(1+\cos\theta+\cos^2\theta+\cos^3\theta+\cdots+\cos^{n-1}\theta+\cdots \text{ to infinitely many terms})$$

$= a \sin\theta$ (sum of an infinite geometric series in which the first term is 1 and $r=\cos\theta$)

$$= a \sin\theta\left(\frac{1}{1-r}\right) = a \sin\theta\left[\frac{(1+r)}{(1-r)(1+r)}\right]$$

$$= a \sin\theta\left[\frac{1+r}{1-r^2}\right] = a \sin\theta\left[\frac{1+\cos\theta}{1-\cos^2\theta}\right]$$

$$= a \sin\theta \frac{2\left(\dfrac{1+\cos\theta}{2}\right)}{\sin^2\theta}$$

$$= 2a\frac{\cos^2\theta/2}{\sin\theta}$$

$$= 2a \csc\theta \cos^2\theta/2$$

PART 2

If $\theta=\pi/4$ then

$$\csc\theta=\sqrt{2} \text{ and } \cos^2\theta/2=\frac{1+\cos\theta}{2}=\frac{1+\sqrt{2}}{2\sqrt{2}}$$

Therefore

$$2a \csc\theta \cos^2\theta/2 = 2a\sqrt{2}\left(\frac{1+\sqrt{2}}{2\sqrt{2}}\right) = a(1+\sqrt{2}) = a+a\sqrt{2} = a+2\left(\frac{a}{\sqrt{2}}\right)$$

where each leg of the specified right triangle is $a/\sqrt{2}$ and the hypotenuse is a.

Solutions were also offered by Richard H. Bates, Milford, N. Y.; Alan Wayne, Baldwin, N. Y.; and an unknown person who neglected to put his name on his solution.

2489. *Proposed by Julius Sumner Miller, El Camino, Calif.*

5. A sphere, a hoop, a disc, and a cube have equal masses. The sphere, hoop, and disc have equal radii. All four start from rest and roll (slide in the case of the cube) down a smooth incline. Which one wins the race?

Solution by the Proposer

Let the plane be s cm. long, and its inclination be θ. The problem may be solved by invoking energy relationships (potential energy at top of incline equal to kinetic energy at the foot) or by using Newton's Second Law, $F=ma$, and its analog for rotation $F\cdot r=I\alpha$. The latter method is used here.

(1) *Consider the Cube:* It slides with an acceleration g sine θ. From $S=\frac{1}{2}at^2$,

$$t_{\text{cube}}=\sqrt{\frac{2S}{g\sin\theta}}.$$

(2) *Consider the sphere:* $FR = I\alpha$ (where I is the moment of inertia about the point of tangency and α is the angular acceleration)
Becomes

$$MgR\sin\theta = \frac{7}{5}MR^2\cdot\frac{a}{R}$$

(since the force Mg acts on the arm $R\sin\theta$, I about the point of tangency is $7/5\ MR^2$ and $\alpha = a/R$)
Hence the acceleration of the sphere is $5/7\ g\sin\alpha$ and

$$t_{\text{sphere}} = \sqrt{\frac{14S}{5g\sin\theta}}.$$

(3) *Consider the Hoop:* $FR = I\alpha$ becomes

$$MgR \text{ sine } \theta = 2MR^2\cdot a/R$$

Hence the acceleration of the hoop is $\frac{1}{2}\ g\sin\theta$ and

$$t_{\text{hoop}} = \sqrt{\frac{4S}{g\sin\theta}}$$

(4) *Consider the disc:* $FR = I$ becomes

$$MgR \text{ sine } \theta = \frac{3}{2}MR^2\cdot a/R$$

Hence the acceleration of the disc is $\frac{2}{3}\ g\sin\theta$ and

$$t_{\text{disc}} = \sqrt{\frac{3S}{g\sin\theta}}$$

Therefore the cube wins!
A solution was also offered by Alan Wayne, Baldwin, N. Y.

2490. *Proposed by Paul D. Thomas, Norman, Okla.*
The distance from the origin to the tangent at a variable point of every curve of a family is directly proportional to the derivative of the arc length with respect to the abscissa of the variable point. Find the equation to the family and its envelope.

Solution by Alan Wayne, Baldwin, N. Y.

Let $P(a, b)$ be any point on the curve $y = f(x)$ of the family. The equation of the tangent line at P is

$$y - b = y'(x - a) \tag{1}$$

where the prime denotes differentiation with respect to x. Putting this equation in the form $y'x - y + (b - ay') = 0$, the distance d from the origin to this line is given by

$$d = |b - ay'|/\sqrt{1 + y'^2} \tag{2}$$

But $d = ks'$, where $s' = ds/dx$, and k is the constant of proportionality. Hence, from (2), replacing a and b by x and y, respectively:

$$xy' - y = k(1 + y'^2). \tag{3}$$

Note that the ambiguity of sign is taken care of by the possible sign of k.

To solve (3), differentiate both members with respect to x, and then divide out the common factor $y''\neq 0$. Then $x=2ky'$. Thus $y=x^2/4k+C$. To evaluate the constant of integration, note that when $x=0$, then $y'=0$, and $y=C$, so that from (3), it follows that $C=-k$. The required family is therefore

$$y=x^2/4k-k. \tag{4}$$

To find the envelope of the family, differentiate both members of (4) with respect to k, and use the result to eliminate k in (4). The envelope is the pair of minimal lines $y=\pm ix$. There is no real envelope.

A solution was also offered by the proposer.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.

For this issue the Honor Roll appears below.

2485. *Benjamin Greenberg, Ramaz High School, New York, N. Y.*

2485. *Richard J. Kerslake, Caroline High School, Denton, Md.*

2486. *Robert J. Gregorac, Euclid High School, Euclid, Ohio.*

PROBLEMS FOR SOLUTION

2509. *Proposed by Julius Sumner Miller, El Camino College.*

From a height h a "loop-the-loop" car comes down its track and runs around the inside of a vertical circular loop of radius R feet. From what height must it start so as not to leave the loop?

2510. *Proposed by Brother Felix John, Philadelphia, Pa.*

Show that $3^{2n+5}+160n^2-56n-243$ is divisible by 512.

2511. *Proposed by Christos B. Glavas, New York, N. Y.*

Take a circle of radius r and suppose that the circle rolls on a line from an initial point O. Find the locus of the point P which is the intersection of the perpendicular from O with the tangent at the point M on the rolling circle. This curve might be christened "Tangential Cycloid."

2512. *Proposed by Brother Felix John, Philadelphia, Pa.*

If $\log(x+z)+\log(x-2y+z)=2\log(x-z)$, show that x, y, and z are in harmonical progression.

2513. *Proposed by Joseph Kennedy, Madison, Wis.*

What groups are isomorphic to the Klein Four Group?

2514. *Proposed by Paul D. Thomas, Norman, Okla.*

Construct a triangle given r_b, r_c, m_a, where r_b, r_c are exradii relative to the sides b and c, and m_a is the median upon the side a.

Traffic Game for children makes fun out of practicing safe driving techniques and observing traffic laws. A simulated steering control turns a life-like steering wheel along a 36-inch moving highway. It has a dashboard and horn too.

BOOKS AND PAMPHLETS RECEIVED

EXPERIMENTAL DESIGN, by Walter T. Federer, *Professor of Biological Statistics in Charge of the Biometrics Unit, Department of Plant Breeding, New York State College of Agriculture, Cornell University, Ithaca, N. Y.* Cloth. Pages xix+544+47. 15×23.5 cm. 1955. The Macmillan Company, 60 Fifth Avenue, New York 11, N. Y. Price $11.00.

CARL FRIEDRICH GAUSS: TITAN OF SCIENCE. A STUDY OF HIS LIFE AND WORK, by G. Waldo Dunnington, Ph.D., *Mmeber of the Faculty of Northwestern State College, Natchitoches, Louisiana.* Cloth. Pages xi+479. 13×20 cm. 1955. Exposition Press, 386 Fourth Avneue, New York 16, N. Y. Price $6.00.

THE REPUBLIC OF INDONESIA, by Dorothy Woodman. Cloth. Pages ix+444. 13.5×21.5 cm. 1955. Philosophical Library, Inc., 15 East 40th Street, New York 16, N. Y. Price $6.00.

ON THE NATURE OF MAN. AN ESSAY IN PRIMITIVE PHILOSOPHY, by Dagobert D. Runes. Cloth. 105 pages. 13.5×21.5 cm. 1956. Philosophical Library, Inc., 15 East 40th Street, New York 16, N. Y. Price $3.00.

MATHEMATICAL ANALYSIS OF ELECTRICAL AND OPTICAL WAVE-MOTION ON THE BASIS OF MAXWELL'S EQUATIONS, by H. Bateman, M.A., Ph.D., *Late Fellow of Trinity College, Cambridge; Johnston Research Scholar, Johns Hopkins University, Baltimore.* Paper. Pages vi+168. 12.5×20.5 cm. Dover Publications, Inc., 1780 Broadway, New York 19, N. Y. Price $1.60.

PARTIAL DIFFERENTIAL EQUATIONS OF MATHEMATICAL PHYSICS, by Arthur Gordon Webster, A.B. (Harv.), Ph.D. (Berol.) Paper. Pages vii+440. 12.5×20.5 cm. Dover Publications, Inc., 1780 Broadway, New York 19, N. Y. Price $1.98.

TRIGONOMETRICAL SERIES, by Antoni Zygmund. Paper. 352 pages. 12.5×20.5 cm. Dover Publications, Inc., 1780 Broadway, New York 19, N. Y. Price $1.85.

THE COMMON SENSE OF THE EXACT SCIENCES, by William Kingdon Clifford. Paper. Pages lxvi+249. 12.5×20.5 cm. Dover Publications, Inc., 1780 Broadway, New York 19, N. Y. Price $1.60.

MATTER AND LIGHT, THE NEW PHYSICS, by Louis De Broglie, *Membre de l'-Institut, Nobel Prize Award, 1927, Professeur à la Faculté, des Sciences de Paris.* Paper. 300 pages. 12.5×20.5 cm. Dover Publications, Inc., 1780 Broadway, New York 19, N. Y. Price $1.60.

EXPLORATIONS IN ARITHMETIC, by Lowry W. Harding, Ph.D., *Professor of Education, The Ohio State University.* Paper. Pages ix+88. 20×28 cm. 1955. Wm. C. Brown Company, Dubuque, Iowa, Price $3.00.

FREE AND INEXPENSIVE LEARNING MATERIALS. Seventh Edition. Paper. Pages viii+244. 14×21.5 cm. 1956. Division of Surveys and Field Services, George Peabody College for Teachers, Nashville 4, Tenn. Price $1.00.

The secret of success in life is for a man to be ready for his opportunity when it comes.

—D'ISRAELI

Never judge a man by his relations, but rather by his companions; his relations are forced on him, while his companions are his own choosing.

—FRANKLIN

BOOK REVIEWS

An Outline of Atomic Physics, Third Edition, by Oswald H. Blackwood, *Late Professor of Physics, University of Pittsburgh;* Thomas H. Osgood, *Dean of the School of Graduate Studies, Michigan State College;* and Arthur E. Ruark, *Temerson Distinguished Service, Professor of Physics, University of Alabama.* Cloth. Pages x+501. 14.5×23 cm. 1955. John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. Price $7.50.

The first edition of this book came out in 1933 and was hailed at once as a leader in a comparatively new subject field. The first revision was in 1937. Now most of the original authors are gone but their book continues as a great textbook for students who have had one year of college physics and want to know something of the development of the subject in recent years. The first ten chapters, now greatly modified and revised, give the essential parts of the original text. These chapters may be easily read and mastered. The remainder of the text deals with the discoveries and development in more recent years. This section is considerably more difficult, both because there has not been sufficient time for a simplification of the theory, and often the theory is not completely stabilized and accepted. The student here must study the different interpretations given and form his own judgment of the tentative conclusions that are given. In these chapters many of the paragraphs may be omitted in a short course without destroying the continuity of thought. Such paragraphs are indicated by a star. These chapters, 10 to 15, give an excellent abstract of the investigations of recent years. Teachers in service, who cannot do enough reading to follow the investigations as they are made, will accomplish much by a careful study of this section.

G. W. W.

One Hundred Mathematical Curiosities, by William R. Ransom, *Walker Professor of Mathematics, Emeritus, Tufts College.* Paper. Pages viii+212. 20×27.5 cm. 1955. J. Weston Walch, Publisher, Box 1075, Portland, Me. Price $3.00.

This book is indeed just what the title indicates, "Mathematical Curiosities." Many of the problems are old, probably all of them, but many have been modified by the author's interpretation and treatment, so that every reader will certainly get many new ideas. They involve just simple arithmetic in some cases, others require algebra, some geometry reasoning and construction, trigonometry, analytical analysis, rectangular and polar coordinates, calculus, and just plain horse sense. Some of them are easy enough for starting the conservation rolling in a social meeting of strangers and will set the fun going. Others will cause the greatest mathematicians to knit their brows. Plenty of fun for everyone for just three dollars.

G. W. W.

Science for Work and Play, Grade 1, by Herman and Nina Schneider. Cloth. 160 pages. 14.5×22 cm. 1954. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $.168.

Science in Your Life for Grade 4, by Herman and Nina Schneider. Cloth. 314 pages. 14.5×22 cm. 1955. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $2.36.

Science in Our World for Grade 5. by Herman and Nina Schneider. Cloth. 314 pages. 14.5×22 cm. 1955. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $2.28.

Science for Today and Tomorrow for Grade 6, by Herman and Nina Schneider. Cloth. 378 pages. 14.5×22 cm. 1955. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $2.44.

Elementary teachers, have you looked over this set of books for use in your science work? The four books listed above constitute part of a set prepared for grade school use. The authors have been mentioned a number of times in past issues of this journal so need no further introduction. They have put up here, as in the past, books that are both highly attractive and very instructive and thought provoking. The first book is largely pictorial, the others containing more reading material as they progress to the higher grades, but all are well illustrated in color. Students who have the advantage of a full course as indicated here will be amply prepared for high school science and little time will be demanded from the teacher in creating and holding interest. Many of the topics taught in the past in high school science will be well known and used by the pupils.

G. W. W.

MORE MODERN WONDERS AND HOW THEY WORK, by Captain Burr W. Leyson. Cloth. 215 pages. 13.0×20.5 cm. 1955. E. P. Dutton and Company, Inc., 300 Fourth Avenue, New York 10, N. Y. Price. $3.50.

This is a new issue of a former, 1952, edition but enlarged by the addition of a chapter on "Dawn of Nuclear Power and the Atomic Submarine *Nautilis*." About one third of the volume is given to rifles, shotguns, revolvers and pistols. Two of the five chapters, so used, tell of the ammunitions for these firearms. Other chapters present: locks, ultra high frequency TV, hydraulic transmission in the automobile, weather instruments and phonograph records. Twenty seven photo illustrations plus many line drawings and diagrams supplement the author's exposition in those sections given to "How they work."

The presentation rates well for readability. Captain Leyson has a creditable record of many books of that quality. However, for this reviewer, he seems to yield, rather too frequently, to a temptation, often prevalent with science writers for the non-technical public. His vocabulary is over-stocked with superlative adjectives. Then, too, the urge to make "complex subjects crystal clear" and in great brevity his "crystals," at times, seem to need a bit more of the polish of precision. That is especially evident in his efforts to phrase radio-activity's half life quality.

There is an ample index for its use as a reference but no bibliography. The "commentary" type of Table of Contents is a desirable aid to the reader who wishes to get a preview of "What it's all about."

B. Clifford Hendricks
Longview, Wash.

CASH AWARDS OFFERED TO SCIENCE TEACHERS

The National Science Teachers Association has been given a field investigation grant by the National Cancer Institute of the National Institutes of Health, U. S. Department of Health, Education, and Welfare. The grant is for the purpose of conducting a project aimed at increasing the effective, appropriate use of cancer information and educational materials in the teaching of high school general science, biology, chemistry, and physics.

Teachers of these high school sciences are invited to submit teaching plans and outlines for achieving the educational goals of the project. Cash awards will be given for those that are judged outstandingly good by a National Awards Committee. The best of these will then be published in a booklet which will be distributed widely among all science teachers.

Robert H. Carleton, Executive Secretary of the National Science Teachers Association will serve as project director. Secretary-editor of the project and the report will be Abraham Raskin, Professor of Physiology and Coordinator of the Sciences at Hunter College, New York City.

Additional information, entry forms, and resource materials may be obtained from the National Science Teachers Association, 1201 Sixteenth Street, N. W., Washington 6, D. C.